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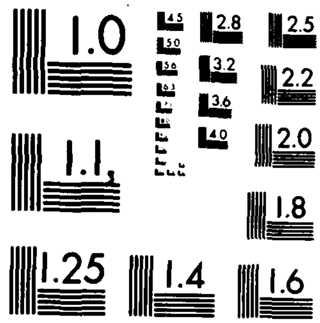

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Summary Proceedings of the Future Navigation Systems Planning Conference

September 1982

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16. Abstract

This publication contains a summary of proceedings of the Federal Aviation Administration (FAA) Future Navigation Planning Conference held at the Federal Aviation Administration Headquarters, Washington, D.C., on August 3-4, 1982. The purpose of the conference was: 1) to present to the users and suppliers of navigation systems, the results of FAA sponsored studies and technical evaluations of navigation systems which are to satisfy air navigation requirements in the post 1995 time period; and 2) to seek industry views on several different options for future air navigation systems preparatory to the FAA developing its recommendations on policies and plans for radionavigation services.

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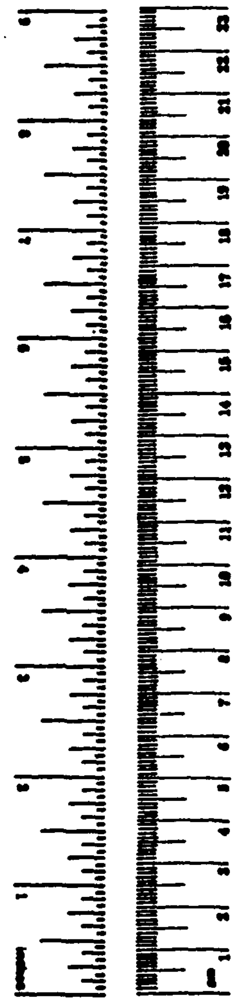
METRIC CONVERSION FACTORS

Approximate Conversions to Metric Measures

Symbol	When You Know	Multiply by	To Find	Symbol
	LENGTH			
in	inches	*2.5	centimeters	cm
ft	feet	30	centimeters	cm
yd	yards	0.9	meters	m
mi	miles	1.6	kilometers	km
	AREA			
in^2	square inches	6.5	square centimeters	cm^2
ft^2	square feet	0.09	square meters	m^2
yd^2	square yards	0.8	square meters	m^2
mi^2	square miles	2.6	square kilometers	km^2
	acres	0.4	hectares	ha
	MASS (weight)			
oz	ounces	28	grams	g
lb	pounds	0.45	kilograms	kg
	short tons (2000 lb)	0.9	tonnes	t
	VOLUME			
tsp	teaspoons	5	milliliters	ml
Tbsp	tablespoons	15	milliliters	ml
fl oz	fluid ounces	30	milliliters	ml
c	cups	0.24	liters	l
pt	pints	0.47	liters	l
qt	quarts	0.95	liters	l
gal	gallons	3.8	liters	l
ft^3	cubic feet	0.03	cubic meters	m^3
yd^3	cubic yards	0.76	cubic meters	m^3
	TEMPERATURE (exact)			
°F	Fahrenheit temperature	5/9 (after subtracting 32)	Celsius temperature	°C

*1 in ≡ 2.54 (exactly). For other exact conversions and more detailed tables, see NBS Misc. Publ. 286, Units of Weights and Measures, Price $2.25, SD Catalog No. C13.10:286.



Approximate Conversions from Metric Measures

Symbol	When You Know	Multiply by	To Find	Symbol
	LENGTH			
mm	millimeters	0.04	inches	in
cm	centimeters	0.4	inches	in
m	meters	3.3	feet	ft
m	meters	1.1	yards	yd
km	kilometers	0.6	miles	mi
	AREA			
cm^2	square centimeters	0.16	square inches	in^2
m^2	square meters	1.2	square yards	yd^2
km^2	square kilometers	0.4	square miles	mi^2
ha	hectares (10,000 m^2)	2.5	acres	
	MASS (weight)			
g	grams	0.035	ounces	oz
kg	kilograms	2.2	pounds	lb
t	tonnes (1000 kg)	1.1	short tons	
	VOLUME			
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l	liters	2.1	pints	pt
l	liters	1.06	quarts	qt
l	liters	0.26	gallons	gal
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m^3	cubic meters	1.3	cubic yards	yd^3
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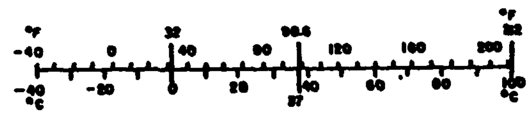

SUMMARY

PROCEEDINGS

OF THE

FUTURE NAVIGATION SYSTEMS

PLANNING CONFERENCE

August 3-4, 1982

Sponsored by the
Federal Aviation Administration
800 Independence Avenue, S.W.
Washington, D.C. 20591

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PREFACE

This publication contains a summary of proceedings of the Federal Aviation Administration (FAA) Future Navigation Systems Planning Conference held at the Federal Aviation Administration Headquarters, Washington, D.C., on August 3-4, 1982. The purpose of the conference was: 1) to present to the users and suppliers of navigation systems, the results of FAA sponsored studies and technical evaluations of navigation systems which are to satisfy air navigation requirements in the post 1995 time period; and 2) to seek industry views on several different options for future air navigation systems preparatory to the FAA developing its recommendations on policies and plans for radionavigation services.

The conference contained keynote remarks delivered by the Administrator, Federal Aviation Administration, and sessions on: VOR and VOR/DME, LORAN-C, Omega/VLF and Navstar GPS navigation systems; operational considerations for air navigation systems; economic issues in navigation system planning; Department of Transportation Radionavigation Working Group activities and plans; and institutional issues in planning future navigation systems. Presentations on FAA technical studies summarized work performed in each particular area. In addition to FAA presentations, the conference contained remarks by a panel of six experts in the field of air navigation and statements from organizations representing a cross section of users of the future navigation system.

These proceedings contain copies of selected conference papers, a summary of the remarks presented by each member of the experts panel and by each representative of the aviation user groups, a summary of FAA's understanding of the consensus reached at the conference, and a list of conference attendees.

These proceedings are not intended to include all material distributed during the Future Navigation Systems Planning Conference, but to incorporate that material which provides the basis for the Conference consensus. The remaining material consisted of technical briefings on the several navigation systems which are the principal candidates for the future navigation system mix. A general discussion of these systems is included in the enclosed paper entitled "Overview of FAA Studies and Findings." Detailed information is contained in "Summary of the FAA's Future Navigation System Mix Evaluation (through May 1982)," Draft Report No. DOT/FAA-EM-82-24 dated August 1982, which was distributed at the conference and is available on request.

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FUTURE NAVIGATION SYSTEMS PLANNING CONFERENCE

Federal Aviation Administration
Washington, D.C.
August 3 and 4, 1982

A G E N D A

Tuesday, August 3, 1982

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9:05	Keynote Remarks	J. Lynn Helms Administrator, FAA
9:40	Overview of FAA Studies and Findings	Neal A. Blake Deputy Associate Administrator, Engineering and Development, FAA

Presentations on Technical Studies

Moderator:
Robert W. Wedan
Director, Systems Research and Development Service, FAA

10:10	VOR and VOR/DME Navigation System Overview	Frank W. Bassett, FAA
10:40	MORNING BREAK	
11:00	Loran-C Overview	George H. Quinn, FAA
11:45	LUNCH BREAK	
1:00	Global Positioning System (GPS) Overview	Jerry Bradley, FAA
1:30	GPS Technical Findings and Flight Test Results	Norman T. Fujisaki, FAA
2:00	GPS Receiver Investigations and Tests	Anthony Buige, FAA
2:30	AFTERNOON BREAK	
2:50	Omega/VLF Overview	George H. Quinn, FAA
3:20	Open Discussion of Technical Presentations	Robert W. Wedan, Moderator

Tuesday, August 3, 1982 Agenda Continued

3:45	Operational Considerations for Air Navigation Systems	H. Wayne Minnick, Air Traffic Service, FAA
4:15	Economic Issues in Navigation System Planning	Harvey B. Safeer Director of Aviation Policy and Plans, FAA
4:45	Adjourn	

Wednesday, August 4, 1982

9:00	Department of Transportation Radionavigation Working Group Activities and Plans	David C. Scull Research and Special Projects Administration, DOT
9:30	Institutional Issues	S. B. Poritzky Director of Systems Engineering Management, FAA
10:00	MORNING BREAK	

10:20 Expert Panel Discussion on Future Navigation System Planning Issues

Mr. Frank B. Brady - Executive Director, Institute of Navigation

Mr. Sven H. Dodington - Avionics Consultant, International Telephone and Telegraph Corporation

Mr. Edward J. King - Chairman of the Board, King Radio Corporation

Mr. John W. Klotz - Aviation Consultant

Mr. Harry Sonnemann - Deputy Chief Engineer, NASA

Mr. Alexander B. Winick - Aviation Consultant

12:00 LUNCH BREAK

1:00 Statements by Organizations Representing Users of the Future Navigation System, and Others

Open Discussion

Closing Remarks

Adjourn Approximately 3:00

SECTION 1

REMARKS OF J. LYNN HELMS, ADMINISTRATOR
FEDERAL AVIATION ADMINISTRATION
FUTURE NAVIGATION SYSTEMS PLANNING CONFERENCE
WASHINGTON, D. C.
AUGUST 3, 1982

In a few months FAA will provide its input to the 1983 DOD/DOT preliminary recommendation on the future navigation system mix, prior to a 1986 decision at the national level. I want your advice and counsel on the needs and wishes of civil aviation prior to making my recommendation. I want to emphasize the remarks I am about to make do not contain, or even imply, a position of pre-determined policy. They are intended to establish a perspective.

The DOT/DOD Federal Radionavigation Plan, which delineates policies and plans for government radionavigation services, had its genesis in the recognition several years ago a) that the country would be well served by a coordinated approach to radionavigation; b) that the Departments of Defense and of Transportation were the responsible providers of radionavigation services in the United States; and c) that by joint, coordinated planning a more efficient and cost-effective navigation system could be achieved for the United States. It was understood, of course, that radionavigation is not a domestic U.S. problem alone, but an international matter impacted by needs, requirements, and wishes far beyond our shores.

There was also a perception that there was a large and cumbersome profusion of overlapping services, specifically tailored to individual modes of transportation, and that this profusion was costing the U.S. a great deal more than was necessary. Finally, there was a strong feeling that a system like the Global Positioning System (NAVSTAR/GPS) could in one sweep get rid of virtually every other radionavigation service, and could do so at an early date to the major economic benefit of the government and the user communities.

We have been at work for some time now to test these perceptions. Over the past several years we have worked with you to try to develop requirements for future radionavigation services. Through formal and informal contacts, and with the help of work done by you through the Institute of Navigation, we developed the civil aviation requirements which are now a part of the Federal Radionavigation Plan. For the past several years we have done a substantial amount of work, by ourselves and in association with DOD and with several States, to learn more and to try to assess the real capabilities of the candidate navigation systems for the future. We have done economic studies to try to evaluate the cost of various navigation system mixes--an extremely difficult task not only because costs to the users are difficult to evaluate, but the question of who will pay for what ground- or space-provided services is murky for systems not provided by FAA itself.

Throughout these two days we will be reporting to you on what we have learned. We expect that you will have preliminary views based on your knowledge and on what you hear at this meeting, but step back with me for a moment and look at the issues broadly from the perspective of U.S. and world aviation, and our long-term interests.

As you know, we have been hard at work creating the National Aviation System Plan and are at work on the National Airspace Review. It is curious that in our examination of aviation's needs, navigation has not surfaced as a major problem. With the

exception of helicopter user needs, we have heard little about the need to make dramatic changes in the navigation system and services provided by the government.

During FAA's New Engineering and Development Initiatives process in 1978 and 1979, when the user community reviewed our technical systems and made a series of recommendations to FAA, navigation was not considered a pressing issue and no major recommendations were made.

In the recent extensive study of over-ocean improvement, conducted by the International Aviation Review Committee, no pressing need for new navigation capability emerged, except for the need to reduce vertical separation above Flight Level 290. And yet, all of us see shortcomings in our present navigation system mix and most of us have been intrigued for many years with the possibility of a single navigation service meeting the full needs of aviation and perhaps all of transportation.

With this as the starting point, let me characterize the candidate systems we have been looking at:

First is VOR/DME, the ICAO Standard worldwide short distance radionavigation service. It's a VHF/UHF line-of-sight system, extremely easy to use and easy to visualize, and very inexpensive to the general aviation user. More than 50 percent of all single-engine general aviation users use VOR and its localizer capability exclusively. It has been the backbone of our route network for years and it serves to support non-precision approaches over much of the country. It has proven to be a highly reliable system. Because it is a relatively short range system, and there is frequently nearby or overlapping coverage, an outage is more a nuisance than a serious problem.

VOR/DME has a number of shortcomings. It is sensitive to siting and terrain. Because it is a line-of-sight system, its low-altitude coverage is limited and it is therefore not really well suited for helicopter operations. While VOR/DME supports area navigation and coupled operations, it is less than optimum for these uses. VOR, with its $\pm$4.5 degree system use accuracy, is not a highly accurate system. DME/DME, an accurate fixing source where coverage exists, is only now beginning to be exploited. A number of successful developments have shown that VOR can be made significantly more accurate and less site-sensitive by installation of Doppler ground antennas, as has been done in the U.K., and several kinds of more accurate multi-lobe VOR concepts have been demonstrated over the years. There are ways to tighten up airborne VOR accuracy at relatively modest cost. Modern DME, more accurate than VOR, can also be improved. Yet we have not chosen over the years to take advantage of those possibilities, primarily because the community has not seen the need.

Omega, a very long-range VLF hyperbolic system, along with a network of U.S. Navy VLF communications facilities, is in wide use--often as a support aid for other navigation methods in civil operations, using a network of eight Omega ground stations located across the world, with U.S. support coming from the U.S Coast Guard. Basic Omega is subject to a variety of diurnal and other environmental effects, and can yield an accuracy on the order of 2-4 nautical miles--clearly not adequate by itself for all domestic operations or non-precision approaches--although it is increasingly used by itself or as an update aid for other systems even across the U.S. in the en route system. It is widely used internationally, often in conjunction with inertial navigation systems. It requires an area navigation computer and

is usually aided by air data systems to minimize the effects of the basic ambiguity and relatively slow data rate of the basic system. Considerable work has been done on differential Omega using a ground receiver and a ground/air communications link at or near the point of use, to calibrate out the larger errors and to transmit corrections to aircraft. This, of course, adds a measure of complexity and cost to the total system. Omega has proven to be a highly valuable system for long-range en route operations but it is an unlikely candidate for use as a short-range navigation system, and it is unsuitable as a single worldwide multi-purpose navigation system.

LORAN-C, another hyperbolic system, but with much shorter base leg spacing than Omega, operating in the low-frequency band, is a system initially intended for sea navigation especially in coastal waters. It has the major advantage of low-altitude coverage. It is a moderately accurate system within its useful area of coverage, 600 miles or more. LORAN-C requires an area navigation computer even in the minimum installation. Its limited range prevents its use as a long range over-ocean aid. Present coverage within the U.S. is incomplete, but means are available to increase its coverage across the U.S. by the addition of a significant number of additional ground stations. LORAN-C is, of course, significantly less site-sensitive than VOR/DME, and permits coverage to be provided in areas where it would be difficult to successfully site point-source systems. LORAN-C service is provided by the Coast Guard; it is used extensively in shipping and is finding increasing aviation use, especially for helicopter operations, and it has attractions for non-precision approaches in mountainous terrain. A new Standard is required for airborne hardware which will include the requirement for detection and warning of the pilot when a cycle slip occurs in order to permit the use of LORAN-C for non-precision approaches.

NAVSTAR/GPS has commanded much of our recent attention. A multiple orbiting satellite system developed to meet military needs, it has already demonstrated very high accuracy not only in its Precision Positioning Service but also in its Standard Positioning Service mode. Given full access to the standard (SPS) signal and a full 24-satellite constellation, non-precision approach accuracy would be available over all parts of the world, as well as high-quality en route navigation both domestically and over oceans. We are convinced that the presently planned 21-satellite constellation (which includes 3 spares) will not do aviation's job, either in terms of the necessary coverage or reliability. When 24 satellites are operating, coverage is adequate; however, temporary gaps will occur when a satellite fails--until a spare satellite can be brought into position. This will result in a moving area where insufficient satellites are available for navigation. At this time, and probably for some time to come, there is a national security need to deny the full accuracy of the system to civil users, and a 500-meter accuracy is talked about for the denied-accuracy mode. While 500 meters meets current RNAV non-precision approach requirements, it would not be adequate when accuracy equivalent to an on-the-field VOR is needed. Once again there is a possibility of providing differential receiving equipment near the point of use with a communications link to the aircraft. (There is a problem here--if a ground receiver can bypass the denial of accuracy, so may an unfriendly power, but perhaps there are ways around it.) GPS users would, of course, require area navigation computers and significant work would be required to assure adequate and timely failure warning to pilots.

Like all systems using area navigation computers, there is more cockpit workload and more blunder possibility than in the use of simple VOR/DME, but automation is and

will surely be available, at a price, to make all area navigation systems user-friendly. The cost of the minimum GPS receiver is likely always to be higher than a VOR/Localizer receiver, but significantly better service can be expected.

If the precision signal were available for civil use from GPS there might be significant value in vertical data as well as horizontal position, although such data is geocentric rather than barometrically referenced. GPS vertical data from the Standard Positioning Service looks to be of limited value.

GPS, and, to a degree, Omega and LORAN-C, have one other attribute which requires careful examination. They are more vulnerable than other systems in that failure of one or perhaps two signal sources can seriously impair service over a very large region. Unfriendly actions which would have a significant but relatively minor effect in short-range systems such as VOR/DME can have a major and potentially catastrophic effect on navigation services if the signal sources were to be disabled.

Inertial navigation systems are now authorized as a sole means of navigation in over-ocean areas. INS is also used on domestic routes when updated periodically from other aids. Such systems are in use either by themselves, or with an Omega backup. A quiet revolution is taking place in inertial navigation systems. While they were plagued for some years with high cost of ownership, the ring-laser gyro is likely to change that situation dramatically in coming years. I noted that Boeing recently announced that the 737-300 would have an inertial reference system offered as standard equipment for that airplane's basic attitude and direction reference, and the system would of course be available, in conjunction with appropriate computers, for navigation. If the use of this kind of inertial reference system grows, such a system, updated if needed by Omega or GPS over oceans, or updated over land by an occasional fix from ground DME facilities, may fulfill the full large-aircraft en route navigation requirement. The degree to which self-contained systems will be used for navigation will be impacted in no small measure by the costs that users perceive themselves incurring for navigation services provided from ground or space.

Two more points round out this picture:

Some people smile when they think of Non-Directional Beacons as part of the future navigation system mix, yet NDB's remain major radionavigation aids to aviation, and their use is growing around the world.

Finally, a word about landing aids. We must move smartly toward taking advantage of the benefits that the Microwave Landing System has to offer both air carriers and general aviation. I want to see more precision landing aids available, not just from FAA, but sponsored by states and municipalities at small fields across the country. MLS is the only real possibility for smaller-field application. It will provide better precision approach and landing guidance for major airports around the world, and will find increasing application in the achievement of needed airport capacity for the diversity of air vehicles using our major airports.

There has been conversation about the use of en route navaids to provide precision approach and landing guidance service, with a focus on the GPS Precision Positioning Service for this application. Of course not all the returns are in, but it does not seem sensible to look for precision approach and landing guidance service from any system where the data sources are thousands of miles away. When the wheels come

close to the runway, it is best to have a continuously and locally monitored signal source anchored to the ground in a way in which the highest possible integrity is achieved. For non-precision approaches by all means, but for precision approach and landing guidance MLS is clearly the answer.

That's my quick rundown of the options we have available.

Let us talk now about costs and international standardization. From our economic studies to date you will hear that long-term costs to users and government, taken together, are not dramatically different for various practical system mixes. But be careful about those numbers. For example, in our cost assessments we have assumed that the aviation community would pay for airborne LORAN-C, but that no cost accrues to aviation users from the ground provision of the LORAN-C service other than stations specifically required to provide the additional coverage required by aviation. For GPS we have assumed that DOT, and therefore civil users, would pay for only the satellites which would be needed beyond the presently planned constellation to achieve adequate coverage and system reliability. (Yet, a recent DOD study on cost recovery for GPS would have aviation pay what I believe is a totally disproportionate part of the cost of GPS.) We assumed that no charge would accrue to FAA or users from Omega.

There is a special cost-sharing question as it relates to GPS. Our preliminary studies show that the costs to the government to deploy, operate and maintain GPS are higher than the combined costs of VOR/DME, Omega, and LORAN C. For avionics, viewed from the year 2005, the aggregate costs to the users (in 1981 dollars with no discounting) are nearly the same for GPS-only versus the current system mix, except for the small general aviation user whose costs would be significantly higher.

If there is a clear long-term military requirement for GPS which must be paid for regardless of civil needs, it would then be cheaper for the Government, and therefore the taxpayers and users, to pay for GPS only, rather than a full GPS constellation plus all or part of the current mix of systems. This assumes, of course, that the costs for GPS which would be allocated to civil users would be a moderate portion of the total cost. Given that the civil share of GPS costs is relatively small, the costs to be recovered from the civil users could be less than the cost of the current system mix. But avionics costs to general aviation would remain higher than for the current system mix, and cost recovery from non-U.S. users would remain a problem.

In your thinking about the future navigation system, I believe you must count on the aviation community paying for what it uses--that there will not be a free lunch, even though there is a long tradition of services which are available and used without charge by civil aviation and other transportation modes. As I have said so often, this Administration expects that users will pay for the services they utilize. When viewed this way, the economic picture in your minds may change. I believe we must assume for the future that the aviation share of new or existing services will be fair--but there will be a share.

While the costs of the different future system alternatives do not point us sharply to one obvious choice, there are differences in the balance of costs between government and users. By far the greatest disparity in cost is to general aviation. Apparently the lowest-cost alternative over the long run for that group is VOR/DME

along with GPS. This option turns out in the long-term to be slightly more advantageous to general aviation, when looked at in current dollars with and without discounting, than the present mix of VOR/DME, Omega for over-ocean operations and LORAN-C for special uses. For general aviation, any option which removes VOR/DME is significantly more expensive than other choices. There is another point: While by the year 2000 or 2005 all avionics would be replaced anyway in the normal replacement cycle, any change from the present system mix will entail transition costs, perhaps at inconvenient times for the users. Transitions, of course, are much easier when new services are perceived to be needed, and are substantially better than the existing services--yet all transitions are painful.

All of you know that FAA is currently modernizing the VORTAC system. The NAS Plan proposes to streamline the network of VOR/DME facilities; it does not include a transition to GPS. As I've said, we felt that GPS was not yet ready for inclusion in the NAS Plan, but we recognized that it might become a highly attractive candidate in the post-1990 era. In the NAS Plan we tried to identify only those new airborne systems which would be cost/beneficial at low technological risk, and which would clearly be needed or desirable in the modernized ATC system. As I see it, the Mode-S transponder with altitude reporting and data link capability is the first and most important new system for the community to consider. MLS offers clear advantages to those who wish to utilize its capabilities in a carefully constructed transition from ILS to MLS. Twenty-five kilohertz communications capability is a relatively small expenditure which may be needed during the transition to full data link service over the years. TCAS as an independent backup to the air traffic control system will be an important and wise investment for those who wish to avail themselves of that capability. You must now help us in making decisions on navigation.

I noted earlier that navigation is an international matter and international standardization will be required for almost any new direction we take. VOR, DME and NDB's are international standard systems, and will no doubt remain so for some years to come. Omega is widely recognized and used, although not officially standardized in the ICAO process. LORAN-C is not, and might have a tough job achieving international standardization. GPS is the most interesting in international terms. The prospects for international standardization, regardless of how attractive GPS may be, are impacted by the fact that it is operated under U.S. military control. Laying aside the problems of cost and cost recovery, if we wished to propose GPS, the job of international standardization might be easier if it were a U.S. civil system managed by the civil administration, but it would be even easier if it were a system agreed to and jointly financed by ICAO or some other form of international operating body. Other countries are looking at civil satellite systems similar in capability to GPS, among them a study by the European Space Agency of a satellite navigation system optimized for civil use. We have done such studies ourselves, and it is clear that a future system optimized for civil aviation, which would utilize larger and higher powered space elements, could make possible a significantly simpler U.S. or global satellite navigation system in the future. The cost of the space portion of the system, however, will be substantial.

But perhaps we should think even more broadly. For years we have studied proposal after proposal for satellite-based surveillance and combined surveillance/navigation/communications systems. FAA itself has developed several. They have all up to now failed to win acceptance because of cost, but that picture will undoubtedly change. We are currently, in house, looking at the capability of Mode-S avionics as

potential transponders for satellite surveillance in the future. Many of us in FAA have been concerned lest a combined surveillance/navigation system have common failure modes which would rob us of the safety benefit we have had over the years by the policy of essentially separating navigation from surveillance. Yet I am sure there are satellite system techniques in which sufficient segregation can be achieved to alleviate that worry. It is appropriate for us to consider whether, in looking toward the 1990's and the turn of the century, the civil community should opt to go for full support and implementation of NAVSTAR/GPS, or whether we should set our sights beyond it--to an advanced civil satellite system of international character, either geostationary or orbiting, which would provide not only navigation but also surveillance and probably digital communications. I am not suggesting the better as the enemy of the good, but it is a matter we should consider. As the International Aviation Review Committee noted in its recent report, "It appears unthinkable to many that the civil aviation community should enter the 21st Century without satellite systems providing cost effective aeronautical mobile communications at least."

Let me finally put my questions to you succinctly:

1. Recognizing that the aviation user community will pay a fair share for all of the services it uses, do you see a need for a change in the navigation system mix--VOR/DME for the domestic short-range system, Omega for over-ocean and long-haul primary or updating service, LORAN-C where available to service helicopters and other special uses, NDB where needed, and presumably increasing use of inertial reference systems in larger aircraft for both domestic and over-ocean operations?

2. Do you believe, and should FAA plan on the basis that area navigation capability should be a minimum requirement for all who wish to use the National Airspace System, or do you believe that simple rho/theta VOR/DME should retain a place in the system up to and beyond the turn of the century? Should we in fact invest in improving VOR/DME accuracy or low-altitude coverage--or both?

3. Is there a clear benefit to transitioning from the present mix to a) a single universal navigation system such as GPS, or b) a combination such as GPS with VOR/DME?

4. Assuming that military needs will require the U.S. deployment of GPS and that only a relatively small share of the cost of GPS operations, for the life of GPS, would be allocated to civil users, how would you then view the use of GPS as the sole future civil radionavigation system?

5. If you believe it is prudent for us to plan on a transition sometime in the 1990's from the present system mix to a satellite-based navigation system--either alone or with VOR/DME--is GPS the system of choice, or should we, prior to making such a decision, undertake one more study--in the U.S. or perhaps internationally--to determine the potential practicality and cost-effectiveness of a satellite-based system which could provide high-quality navigation service, but could also safely, in a functionally segregated way, provide ATC surveillance and digital communications capability?

I ask you to ponder these questions, give us your initial reactions at this meeting and then offer us your more formal and considered views within the next two months.

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SECTION 2

REMARKS OF NEAL A. BLAKE
DEPUTY ASSOCIATE ADMINISTRATOR
FOR ENGINEERING AND DEVELOPMENT
FEDERAL AVIATION ADMINISTRATION

FUTURE NAVIGATION SYSTEMS PLANNING CONFERENCE
WASHINGTON, D.C.
AUGUST 3, 1982

As the day proceeds, you will hear briefings on the work we have done in preparation for making the FAA preliminary recommendation on a future navigation system mix. Mr. Helms has laid out what we believe are the key questions which must be addressed in making such a recommendation. I would like to spend a few minutes presenting a brief overview of the work which has been done and a summary of some of our findings, particularly as they relate to the issues and questions we would like you to address.

Our work over the last several years has concentrated on what we believe are the most likely candidates for the future navigation system mix. They are: VOR, VOR/DME and VORTAC, LORAN-C, NAVSTAR/GPS, and OMEGA. We also looked at Non-Directional Beacons which remain a major worldwide navigation aid and an integral part of our precision approach system, and Inertial Navigation Systems which already have a major role and whose implementation level may have a significant future impact on the need for external-referenced aids. Since precision landing systems are covered by the Federal Radionavigation Plan, we looked again at ILS and MLS. We did not undertake new evaluation efforts on those systems as the key decisions have been made and FAA is proceeding with the transition planning associated with the phase-over to MLS.

In looking at the candidate navigation systems, we examined a number of technical factors which characterize the systems. They included: accuracy, coverage, integrity, reliability, and operational suitability. While these factors are not mutually independent--nor always directly comparable among the candidate systems--they offer a relatively straight-forward evaluation methodology from which useful results can be derived. In using these factors to compare systems, basic differences quickly come into focus.

- For example, accuracy may be dependent on the measurement point of reference with respect to signal origin, as in VOR/DME, or on the crossing angle of lines-of-position as in LORAN-C, OMEGA, and GPS. System accuracy is also highly dependent on user avionics performance. To constrain this latter variable, we postulated Minimum Operational Performance Standards for each of the systems. Coverage comparisons present similar problems.

- Integrity is defined as the ability of a system to assure the user that he will always receive truthful information--that is, the system does not lie--and to provide warnings to the pilot when the navigation information presented is unusable. Different techniques are used to insure integrity, and direct comparisons are difficult.

- Reliability and system availability are defined as the probability that a system will provide adequate service over a given period of time. In our work,

we have treated these measures primarily with respect to the signal-in-space. Avionics reliability is, of course, important, and we have assumed that the marketplace would assure the availability of equipment providing satisfactory performance. Redundant avionics installations, of course, permit achievement of very high levels of system availability.

- Operational suitability is one of the most difficult topics to quantify. We have thought of it as the measure of the ability of a navigation system or mix of systems to be flown safely and efficiently in the National Airspace System. The factors which influence operational suitability include pilot workload, pilot blunder potential, use of the system in single-pilot aircraft, the capability of the system to integrate well into the ATC system, and pilot confidence or comfort in the use of the system.

There are two other criteria which must be considered:

- One is the economic issue--the comparison of costs and cost/benefit ratios between systems and between system mixes, the distribution of costs between the user and the government, and the economic problems of system transition. You will hear more about this later.

- Finally, and in some ways most important, are institutional issues. Mr. Helms has already spoken to you of those. Basically they relate to cost recovery, control of signal access, control of accuracy, susceptibility to interference, and the problems of international standardization. More about these also this afternoon.

Before proceeding further, I would like to define several of the terms relating to accuracy. Starting with the IEEE Handbook definition that "accuracy is the degree of correctness with which a measured value agrees with the true value," several additional terms need to be clear:

- Signal-in-space accuracy is defined as the quality of information of the signal which can be received and processed in the user's equipment.

- System accuracy is the expected accuracy of a radio navigation system exclusive of errors which may be introduced by the user, and of geodetic or cartographic errors. For this definition, the errors introduced by the receiving and display equipment are aggregated with the signal-in-space error.

- System use accuracy is a term established by ICAO which encompasses signal-in-space error, airborne receiver and display errors, and flight technical error. Combined in a proper statistical manner, the system use accuracy will determine the probability of an aircraft remaining within specified limits, and is the basis for the establishment of route widths and protection areas.

We have not attempted to quantify or include blunders in these assessments because of their non-systematic character, but blunder potential must be assessed for each of the systems and their mechanizations.

In assessing the capability of various navigation systems, we made a going-in assumption that a new system or system mix, in order to be acceptable, must fully

meet the navigation requirements which are to be found in the Federal Radionavigation Plan. These requirements are the ones originally stated by the user community. In general, the systems meeting these requirements will need to provide service that is as good as, and, in some cases, somewhat better than, the system or system mix they replace.

Looking at Figure 1, it becomes clear that the most stringent aviation requirement, excluding precision approach and landing systems, concerns non-precision approaches. Recognizing that in today's operations, an on- or near-airport VOR properly located can yield a system accuracy on the order of 100 meters 2drms, we have used that number as the basic requirement for replacement systems providing non-precision approach capability. In areas where lower precision can be accepted for non-precision approaches, the accuracy requirements for area navigation equipment, as described in Advisory Circular 9045A, which calls for 600 meters, 2drms, are used. The requirements for other areas are shown in the figure.

Figure 2 is a comparison of the different navigation system accuracies and the civil aviation navigation requirements projected for 1995. It shows that none of the systems meets the requirements for all phases of flight.

NAVSTAR/GPS has the potential for meeting all accuracy requirements, with the exception of precision approach and landing, if the full capability Standard Positioning Service accuracy is available for civil use. If, however, the accuracy of the Standard Positioning Service is degraded to 500 meters 2drms, as proposed by the DOD, NAVSTAR/GPS will still meet the requirements for oceanic, en route, and terminal phases of flight, but it will not meet the non-precision approach requirement where accuracy equivalent to an on-airport VOR is needed.

VOR/DME meets en route, terminal, and non-precision approach requirements where coverage exists, but it must be supplemented by other systems for oceanic use, and for areas where accuracy and coverage are insufficient for certain helicopter and other special operations.

OMEGA-VLF can provide coverage for oceanic and long-haul en route operations, and could be supplemented by differential OMEGA service to meet terminal requirements, but it would not fully meet even the reduced accuracy RNAV non-precision approach requirements.

LORAN-C cannot meet oceanic requirements, but could meet en route and terminal requirements. In most areas it would not meet the non-precision approach accuracy requirement of 100 meters 2drms, but would meet the reduced accuracy RNAV non-precision approach requirements.

Several different system <u>mixes</u>, however, can meet all navigation accuracy requirements.

With respect to coverage, Figure 3 summarizes the coverage of the several systems in brief terms.

Trying to boil down the various options to the most practical combinations or necessary mixes requires certain assumptions. You will hear later in the day that in order for LORAN-C to be a useful candidate for civil aviation, additional coverage must be provided, and certain additional protections must be provided in

airborne systems to provide the necessary integrity, particularly for non-precision approach use.

For GPS to be a viable candidate, more satellites would be needed than are currently planned. Additional capabilities to insure integrity must be provided either in the system itself, in the airborne receiving equipment, or both.

But let us assume that those additional capabilities are provided--that it is fair to talk about systems as they could be, not as they are right now. The practical mixes (excluding ILS/MLS) for the future, using these criteria, are the following:

- First, the present mix of OMEGA-VLF for over-ocean and certain domestic en route operations, VOR/DME as the standard short-range system, and Loran-C and possibly differential OMEGA to meet special requirements.

  NDB's would be used where no other services are available, and it would be expected that a number of users would utilize INS, updated as needed, by other services.

- The next possible mix would simply substitute LORAN-C for VOR/DME, and assumes that with appropriate care, sufficient non-precision approach capability can be achieved with LORAN-C. Transition to LORAN-C from VOR/DME, neglecting transition problems, would have the greatest cost impact on the small general aviation aircraft, but clearly offers benefits to helicopter operators.

- The next candidate is GPS alone, and it can meet technical requirements in the undegraded Standard Positioning Service mode for all needs. Economic factors bear heavily on the GPS choice, with the element of aviation most heavily impacted again being the low end of the general aviation spectrum.

- Taking this group into consideration, another system mix becomes attractive: GPS, along with retention of a VOR/DME network.

Let me touch now on some other factors where our investigations have confirmed what many of us have surmised:

All of the systems except VOR/DME and NDB require the use of area navigation computers in the aircraft as basic equipment. All of the systems other than VOR/DME and NDB are more abstract in that they do not fix in the user's mind the physical location of the signal source. Experience has shown that all area navigation systems tend to introduce more blunders, if only because more data input is required of the user. Automation and different kinds of displays may change that situation but, of course, at a price for the equipment.

Propagation characteristics of the different systems also require consideration. As a matter of history, we have over the years gone up in frequency to avoid propagation effects, even though in systems like VOR/DME the penalty of line-of-sight limitations came hand-in-hand with the higher frequency. OMEGA is highly susceptible to propagation effects, but many of them are predictable and can be dealt with through additional capabilities in airborne equipment, or differential equipment on the ground.

Similarly, for LORAN-C, an LF system, propagation effects were apparent in our evaluation--as can be seen from Figure 4, which shows the seasonal instability as seen in a fixed LORAN-C monitor installed at London, Kentucky. This error equates to a crosstrack error of about 200 meters at London, Kentucky.

A choice of LORAN-C would require very careful avionics installation and aircraft bonding--safeguards to reduce noise and interference effects. LORAN-C is significantly more sensitive to interference than some of the other systems. Experience in the use of LORAN-C, as earlier in systems like DECCA, shows that great care must be taken in assuring that the lines of position fall and remain in the right places. They are affected by local variations which may require one-time or periodic calibration.

VOR/DME, which we all know a great deal about, is subject to some problems which I won't describe here today. There are a number of ways available to improve that system beyond its present installed capability, if that should prove desirable.

With respect to OMEGA, our studies have shown that based on limited data, accuracy within good coverage can be achieved to approximately 0.25 miles, 2drms--using a differential system. This is not quite good enough to meet the non-precision approach requirements, but a great deal better than no capability at all, especially in remote locations where provision of other services might be difficult. Looking at the coverage of OMEGA, our studies verified the predicted coverage and determined that domestic U.S. coverage is marginal at best.

The relatively slow data rate of OMEGA and the need to sequentially gather the data from the remote stations for processing in the aircraft introduce a system lag. Our conclusion is that OMEGA can provide primary navigation service on oceanic routes and supplementary service on domestic routes, but that domestic U.S. coverage is incomplete.

There is another problem with OMEGA, which it shares with INS. OMEGA depends on continuity of operation in order to provide position data. OMEGA is an ambiguous system which requires auxiliary aids--air data systems, INS, or other dead-reckoning capability to assure continuity of position information. OMEGA and INS both must operate continuously if they are to provide navigation information--unlike GPS, VOR/DME, and LORAN-C.

Another concern is the problem of display lag. OMEGA, by nature, is a relatively slow system which has a significant time lag in its display. GPS can provide a much faster update and display, but at the price of more sophisticated circuitry in the aircraft.

GPS, installed in a full constellation and assuming a 10° masking angle in the vehicle antennas, suffers little from external anomalies, but great care must be taken in the monitoring and fault detection to assure that pilots are rapidly warned of system faults.

There has been discussion of differential GPS, in which monitor sites would be established near or at the point of use, appropriate corrections applied, and information given to the aircraft about the signal status and necessary corrections. The problem, as in OMEGA, is that it requires ground facilities and appropriate communications links to the aircraft, which represents an additional cost for the

system. It gives rise to the inevitable question--if a fairly expensive monitoring, correction, and communications mechanism is necessary, why not simply put a low-cost TVOR at the point of use and achieve the same result?

Our work to date has indicated significant position shifts when it is necessary to shift from one satellite to another during non-precision approach operations, although it appears that that problem can be resolved if a full satellite constellation is available and appropriate airborne receiver designs are used.

More difficult is the problem of acquisition and reacquisition in GPS. In our work so far, the time required for GPS initial signal acquisition ranged from 5 to 14 minutes; for signal interruptions of less than 1 minute, 1 to 3 minutes were needed to reacquire the signals. This raises some question as to system operational suitability. The GPS Z set, with which we have been experimenting, was able to maintain lock in various aircraft maneuvers. While accuracy was degraded during these maneuvers, recovery to acceptable accuracy was rapid and did not appear to be a serious problem.

There is a question about degraded signal operations with GPS. If artificial means are used to introduce errors of 500 meters 2drms, and those errors are introduced in a drifting fashion, the drift frequency becomes important in the use of the system during non-precision approaches. If the drift is rapid enough, it can cause confusion to a pilot watching the runway appear to move on successive approaches. This problem is less significant if the drift period is relatively long.

Another problem to be considered is the question of charting. Since all systems except VOR/DME and NDB are basically area navigation systems, means must be chosen and agreed to on how charting and fix data are to be displayed to pilots and controllers. In order to optimally use these systems in air traffic contol, specific fix points must be established, preferably in a uniform fashion. Simplest of these schemes, from both user and ATC's point of view, is a system of fix points similar to those used currently in VOR/DME. Appropriate transformation needs to be done in the aircraft with an appropriate data base to convert time differences or lines of position intersections into such a system of fix designations.

Alternatively, latitude/longitude reference systems can be used, but these may introduce more difficulties, especially into the general aviation cockpit. This problem is somewhat more difficult in the use of LORAN-C where, as you saw, there are significant seasonal variations. In addition, it may be necessary for high-accuracy operations to utilize fixes referenced to time difference lines instead of using computations based on latitude/longitude coordinates.

There is yet another point which relates to the projected future use of Inertial Navigation Systems. If we believe that inertial reference systems of high quality will find their way into domestic aircraft as they have into international aircraft, and the question of user charges remains with us, it is likely that some users will wish to utilize the INS capability and will, therefore, have a lesser requirement for either satellite or ground-referenced navigation aids. Inertial Navigation Systems are authorized for sole use in over-ocean operations today, and the INS/OMEGA combination has become almost standard. International aircraft would, of course, be able equally to use GPS. In the domestic environment, once again the INS/GPS combination has attractions; but the existing VOR/DME network, perhaps using only DME updates for INS, may provide all the service that an INS-equipped aircraft needs.

These questions will depend heavily on the actual cost assessed to users for the various navigation services.

As you can see, there is no obvious choice. Several mixes are possible, and we need your guidance as to the most practical ones. You will hear this afternoon that based on the preliminary economic analysis alone, two choices emerge as most attractive:

a. one being the present mix of VOR/DME and OMEGA, with LORAN-C available for special applications (with MLS for final approach and landing guidance, and NDB's where no other services are available);

b. and a mix of GPS, with VOR/DME retained for the lower-end general aviation application (and MLS and NDB as before).

   GPS alone can meet world requirements with the Standard Positioning Service in the undegraded mode, but the long-term costs to the low-end general aviation user remain higher than the other choices.

Let me spend a moment to explore the future prospects for satellite services, both for navigation and for broader application. Our own studies have shown that while GPS is a highly capable system, it is more complex than it needs to be for civil applications alone. Our studies, and the studies currently underway in Europe, appear to show that a different signal format could yield sufficient capability, prospectively at lower cost, especially for the user equipment.

Mr. Helms also asked us to think about the possibility of a future satellite system, either geostationary or orbiting, which could provide more than navigation service. The issue, finally, is more the cost of such capability than the technical possibilities.

Consideration of such systems started during the 1960 time period. In the early 1970's, the DOT studies conducted under the Advanced Air Traffic Management System program postulated several alternative concepts which were shown to be technically feasible, but costly. The AATMS concept offered a constellation of satellites over the continental U.S. and contiguous oceanic regions for surveillance, navigation, and data link communications; but postulated the use of the Discrete Address Beacon System (now Mode S) in high-density airspace regions to obtain aircraft location and identification and to provide data link communications from ground to aircraft. AATMS also postulated a high level of automation, and it became clear in the evaluation process that the potential cost savings attributed to the AATMS concept were due more to automation than they were to the use of satellites.

FAA also investigated a concept called ASTRO-DABS in the early 1970's, which postulated a capability for surveillance and data link as well as a navigation mode and an air-to-air collision avoidance capability. Once again, system costs were a stumbling block although, in that system, avionics costs were thought to be competitive with ground-based system alternatives.

We are currently investigating the possibility of using the Mode S transponder as the aircraft transponder source for a satellite-based surveillance and data link system. Once again, the major current constraint is cost, but we believe means are available to make systems like this practical in years to come. As Mr. Helms said,

there have been many proposals and ideas for satellite-based communications, surveillance, and navigation systems. With larger space structures and more satellite power, avionics costs will no doubt come down, and it is appropriate for the community, as well as FAA, to consider whether such systems offer more promise in the long run than GPS.

The choices are difficult. A number of the decisions, in spite of significant technical information which has become available, will remain judgmental. We need your thoughts and views to assist FAA and DOT in the definition of the future system mix.

Civil Aviation Radionavigation Accuracy Criteria

Phase of Flight	Source	System Use
Oceanic	——	6.2nm 2drms
En Route	1,000m 2drms	3,600m 2drms
Terminal	500m 2drms	1,800m 2drms
Non-Precision Approach	100m 2drms	150m 2drms
Precision Landing		
Horizontal	4.5m 2σ	6.1m 2σ
Vertical	0.5m 2σ	0.6m 2σ

ACCURACY COMPARISON
(System Accuracy in Meters $2d_{rms}$)

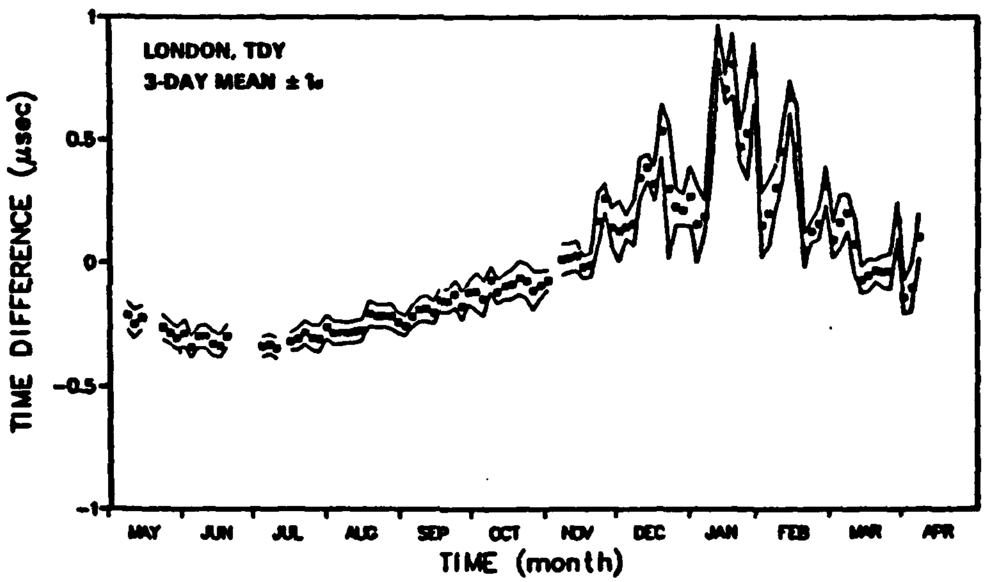
SYSTEM \ PHASE OF FLIGHT	OCEANIC	EN ROUTE	TERMINAL	NON-PRECISION APPROACH	PRECISION APPROACH
PROJECTED REQUIREMENTS					
(Signal-In-Space) System	AC 120-33	(1,000) 3,150	(500) 1,600	(100) 150	($\pm$4.1 Lat. 2σ) ($\mp$0.5 Vert. 2σ)
VOR	N/A	3,150	1,600	88	N/A
LORAN-C	N/A	370	370	370	N/A
NAVSTAR/GPS	87	87	87	87	N/A
OMEGA	1-4 nmi	1-4 nmi	1-4 nmi	1-4 nmi	N/A
INERTIAL	1.6 nmi/hr	1.6 nmi/hr	1.6 nmi/hr	1.6 nmi/hr	N/A
ILS/MLS	N/A	N/A	N/A	N/A	(-4.1 Lat. 2σ) (-0.5 Vert. 2σ)

$$\text{System Accuracy} = \sqrt{(\text{Signal-in-Space Error})^2 + (\text{Avionics Error})^2 + (\text{Display Error})^2}$$

SYSTEM COVERAGE

SYSTEM	AREAS WITHOUT COVERAGE	COMMENTS
VOR/DME	LOW ALTITUDE (EXCEPT CLOSE TO FACILITY) OFF-SHORE, OCEANIC, REMOTE AREAS	
LORAN-C	OCEANIC (SOME LIMITED COVERAGE)	16 ADDITIONAL FACILITIES IN CONUS PLUS OTHERS
NAVSTAR GPS	-NONE -	24 SATELLITE CONFIGURATION
OMEGA/VLF	-NONE -	OMEGA ALONE HAS SOME AREAS WITHOUT COVERAGE
NDB	OCEANIC (SOME LIMITED SERVICE)	MAX. RANGE FOR FLT. INSPECTION IS 75 NM.
INERTIAL	-NONE -	
ILS	ALL AREAS EXCEPT TERMINAL	COVERAGE IS LIMITED TO TERMINAL AREA
MLS	ALL AREAS EXCEPT TERMINAL	COVERAGE IS LIMITED TO TERMINAL AREA

LONDON MONITOR DATA REVEAL 1.5 μsec PEAK-TO-PEAK TD VARIATIONS



SECTION 3

REMARKS OF LCDR WAYNE MINNICK
EN ROUTE PROCEDURES BRANCH
AIR TRAFFIC SERVICE
FEDERAL AVIATION ADMINISTRATION

FUTURE NAVIGATION SYSTEMS PLANNING CONFERENCE
WASHINGTON, D.C.
AUGUST 3, 1982

OPERATIONAL CONSIDERATIONS FOR AIR NAVIGATION SYSTEMS

Operational considerations for air navigation systems may be grouped into four topical areas. These are:

1. Accuracy
2. Efficiency
3. Flexibility
4. Integration

We, in the Air Traffic Service, believe that each of these areas is of vital concern to the air traffic control (ATC) system, for both today's methods of air navigation and those which may evolve over the next two decades. We also believe that they must be considered within the light of today's system, as well as plans and programs which are likely to change that system's complexion.

When we speak of these four areas, we are doing so from our perspective. That perspective is, of course, primarily influenced by our responsibility for providing safe and efficient ATC services to users of the National Airspace System. Accordingly, the meanings we attach to these four topical areas are intimately related to our responsibility, our plans, programs, and internal procedures, and the tools that we have available to us. To give you a better understanding of how we view these operational considerations, I will speak to each of the four areas, briefly touch upon the National Airspace System Plan which we believe is important to this forum, and lastly, say a few words about a part of the National Airspace Review that will address the current system's route structure, policy, and practices.

ACCURACY

Accuracy has been defined as "the degree of correctness with which a measured value agrees with the true value." Obviously, we need a high degree of accuracy in air traffic control. Given the fact that airspace is a finite national asset, we need to have the capability of using all of it as efficiently as we can, especially in light of current and forecast air traffic demands on the system. Since both the practical determination of accuracy from the air navigation standpoint and the separation standards used by air traffic control are statistical in nature, and are interrelated, the former can, and does, exert considerable influence on the latter. This influence is revealed by the varying amount of protected airspace required by ATC for different types of air navigation systems. In turn, it is manifested in our procedural and airspace design, many of the parameters used in our automated systems, and in our near term planning.

As we move further toward the year 2000, we expect to introduce progressively higher levels of automation at all of our air traffic facilities. We foresee that this movement will result in not only an improved ability to do our job but a change in the role of controllers to one of being more passive, rather than continuing the dynamic role they play today. Given this trend, we believe that work needs to continue on exploring methods of achieving a commonly agreed to coordinate system for navigation and air traffic control automation.

Accordingly, we view accuracy as an operational consideration which will weigh heavily in the design of our ground based systems for air traffic control. Ideally, improvements in accuracy will be achieved and are desired in all phases of flight.

EFFICIENCY

Efficiency, in our view, is the ability to utilize airspace and airport capacity to the maximum by all users; yet in a manner which ensures a very high level of safety. To accomplish this, air navigation systems need to be compatible with the air traffic control system. They must provide the pilot the capability of rapidly and accurately complying with controller clearances and instructions, and they must be reliable.

All other things being equal, improved accuracy directly bears on efficiency, enabling us to confidently and safely place more aircraft in a given amount of airspace and increase arrival rates to airports.

FLEXIBILITY

There are few occupational areas that are as dynamic and ever-changing as aviation. We believe that air navigation systems need to be sufficiently flexible to accommodate changes to the national system of routes and air traffic control procedures in a disciplined, evolutionary manner. This type of flexibility will permit progressive improvements to our system in a cost effective manner for both users and the government, with minimal inconvenience to either.

Flexibility also includes the ability for interchanging information between pilots and controllers in terms that are recognizable to both. While currently this interchange is done verbally for the most part, our plans for higher levels of automation in our air traffic facilities suggest that this interchange be accomplished more and more through automated means.

INTEGRATION

Today's network of VOR's, VORTAC's, VOR/DME's, and the associated airways/jet routes shape the nation's air traffic control system. They provide controllers the ability to structure air traffic in a manageable way and provide a means for the common interchange of navigation information. We believe that the need for this highly structured system will persist, although we can foresee the possibility of it diminishing in importance as we move into higher levels of automation. Nonetheless, we believe that future air navigation systems will need to be able to provide pilots with navigation information which will enable conformance to a fixed airway/route structure, as well as prescribed departure and arrival routes. To be sure, we believe that we will have an ever-increasing ability to provide for deviations, but the volume of air traffic in the major hub areas will probably continue to limit our ability in this area.

Other aspects of this operational consideration include the ability to define fixes in a way that is consistent with the overall structure and the versatility to conform to traffic flows where necessary, while retaining the ability to fly optimum routes and profiles when conformance is not required.

In summary, we believe it is essential that future systems lend themselves to being easily integrated into the overall air traffic control system. Further, this integration should apply to all phases of flight, from takeoff to touchdown. And, where applicable, transition from domestic to international flight, and vice versa, should be possible without dedicated involvement by controllers.

These four topical areas of consideration for air navigation systems have a bearing on several programs that the Air Traffic Service has initiated over the past two years, as we strive to improve and rebuild the ATC system. They also bear on some of our most pressing needs for the near and long term.

We have found through our experience with "Operation Free Flight" that a 2% fuel savings is certainly possible by permitting user preferred direct routings between city-pairs by aircraft with suitable navigation equipment. We learned that our ground system has the flexibility to accommodate most such flights at higher altitudes without disrupting service to others. We intend to continue our work in this regard, exploring other ways to achieve greater fuel efficiency.

We have used our knowledge from "Operation Free Flight" and other programs such as En Route Metering and optimum descent profiles, to completely redesign every en route sector within the 20 Air Route Traffic Control Centers (ARTCC) in the contiguous United States. This program was in direct response to increasing demands for system flexibility and fuel-efficiency, and its objective was to optimize overall system design to better serve traffic flows throughout the country and the needs of users. Near the end of this calendar year and early 1983, the changes in sector design and center boundaries that the ARTCC Resectorization Program has accomplished will become effective.

Today, we have several pressing needs in the highly variable and complex terminal environment. The mix of aircraft with varying performance and navigational capabilities present challenging and unique problems for the air traffic control system that require constant attention. The capabilities of STOL aircraft and helicopters, for example, remain to be fully exploited.

While MLS will undoubtedly assist us in achieving better utilization of airspace and airports where it is installed, we believe that gains can also be made in new or improved air navigation systems that give pilots the flexibilty to accurately fly routes and profiles that are outside the major flow of traffic to primary runways where they are capable of using shorter, secondary runways or less congested satellite airports.

To be cost effective, we need to ensure that new initiatives in all of these areas are developed in a mutually beneficial fashion in order to avoid an imbalance between advanced air navigation avionics and advanced air traffic control systems.

Now that I have briefly described our operational considerations for future air navigation systems, I would like to touch upon the National Airspace System Plan (NASP).

As Mr. Helms mentioned earlier today, navigational issues did not surface as major problems during the development of the NASP or the National Airspace Review, which I shall address momentarily. However, we believe that both the NASP and the National Airspace Review can provide this forum with a perspective which will greatly assist you in your deliberations.

The NASP is a comprehensive plan for modernizing and improving ATC and airway facilities services from now to the year 2000.

The plan addresses the compelling problems of how best to accommodate spiraling demands for aviation services, constrain costs, recast the required technical framework, and deal with aging facilities.

In accomplishing these objectives, the plan advances certain assumptions, conclusions, and implications which bear on air navigation systems, either directly or indirectly.

The decision that ATC will remain fundamentally ground-based is one example, and the goal of achieving the highest practicable level of ATC automation is another. Certainly, many other parts of the NASP could be cited, but that is not my purpose today. Rather, I want only to remind you of the NASP because of its importance in shaping our future directions and our operational considerations.

Lastly, ladies and gentlemen, I want to invite your attention today to the National Airspace Review and, in particular, one task group that will be studying an area of direct interest to this forum.

The National Airspace Review (NAR) is a 42 month program that systematically will review all parts of the system. Most importantly, it involves the active participation of this country's aviation interests in its organization, seeking their input and recommendations. The outcome of this program is expected to provide us with an improved ATC system from the standpoint of efficiency and effectiveness.

One of the NAR Task Groups, Task Group 1-3, will be looking at the subject of "routes," and commencing in September, will review current policy on random routes and their application in the National Airspace Sytem (NAS). We will be determining user requirements and discussing problem areas which need resolution. Recommendations will be developed concerning our "Operation Free Flight" evaluation, that was conducted in 1980 and 1981, and ways to implement an expanded random route concept in the NAS. A copy of the draft agenda for this first working session has been made available to you.

Ladies and gentlemen, that concludes my remarks today. I have briefly described four important operational considerations for future air navigation systems and attempted to explain how they are viewed by the Air Traffic Service. Accuracy, efficiency, flexibility, and integration--each important considerations which we believe must be viewed collectively and in the light of today's system and its planned modifications.

Thank you.

NATIONAL AIRSPACE REVIEW

Task Group 1-3 Routes

Scheduled Agenda

Tuesday

September 7, 1982

1100	Chairman's introduction and opening comments
1115	Briefing by Mr. John Watterson, NAR Program Management Staff, "The NAR Program"
1200 - 1300	Lunch
1300	Chairman's discussion of ground rules for meetings
1330	Briefing by Mr. Jack Graham, Aerospace Industries Association, "Types and Number of RNAV Avionics in Use Today"
1400	Question and answer period--open forum
1415	Chairman's overview of the task group's charge and study period
1445	Discussion period--group members
1600	Adjourn

Scheduled Agenda

Wednesday

September 8, 1982

0900	Discussion of users' en route requirements for random routing--open forum
1000	Briefing by Mr. Myron Collier, National Business Aircraft Association, "RNAV's Fringe Benefits to Pilots"
1030	Question and answer period--open forum
1045	Round table discussion of users needs, types and categories of RNAV avionics--group members
1200 - 1300	Lunch
1300	Briefing by Mr. Charles Taylor, FAA Southern Region, Airspace and Procedures Branch (ASO-530), "Current System Requirements for Random Routes"
1330	Question and answer period--open forum
1345	Discussion period--open forum
1600	Adjourn

NATIONAL AIRSPACE REVIEW

Task Group 1-3 Routes

Scheduled Agenda

Thursday

September 9, 1982

0900	Review of minutes and corrections—chairman
0930	Briefing by (to be announced), "Software Enhancements for the Future"
1000	Question and answer period—open forum
1015	Requirements summation period—group members
1200 - 1300	Lunch
1300	Briefing by Mr. Richard Rucker, The MITRE Corporation, "Designing ATC Automation to Accommodate User Preferred Routes"
1345	Question and answer period—open forum
1400	Requirements summation period—group members
1600	Adjourn

Scheduled Agenda

Friday

September 10, 1982

0900	Review of minutes and corrections—chairman
0930	Stipulation of requirements for en route random routing—group members
1200 - 1300	Lunch
1300	Wrap-up requirements list—group members
1600	Adjourn

NATIONAL AIRSPACE REVIEW

Task Group 1-3 Routes

Scheduled Agenda

Monday

September 13, 1982

0900	Review of minutes and corrections—chairman
0930	Briefing by Mr. George Weimar, FAA Southern Region, Operations Branch (ASO-540), "Operation Free Flight"
1000	Briefing by Mr. Gary Church, Air Transport Association, "Operation Free Flight - Participating Airlines Experience"
1030	Question and answer period—open forum
1200 - 1300	Lunch
1300	Discussion of the "Operation Free Flight" concept and methodology and its applicability—open forum
1600	Adjourn

Tuesday

September 14, 1982

0900	Review of minutes and corrections—chairman
0930	Wrap-up review of "Operation Free Flight"
1200 - 1300	Lunch
1300	Conduct examination of existing procedures for filing random routes—open forum
1600	Adjourn

Wednesday

September 15, 1982

0900	Review of minutes and corrections—chairman
0930	Continue discussion of existing procedures—open forum
1200 - 1300	Lunch
1300	Briefing by Mr. Jim Burns, FAA Air Traffic Service, Cartographic Standards Branch (AAT-210), "Charting - Plans and Issues"
1330	Question and answer period—open forum
1345	Stipulation of improvements needed or alternative methods to file random routes—group members
1600	Adjourn

NATIONAL AIRSPACE REVIEW

Task Group 1-3 Routes

Scheduled Agenda

Thursday

September 16, 1982

0900	Review of minutes and corrections--chairman
0930	Wrap-up of previous day's activity--group members
1200 - 1300	Lunch
1300	Briefing by Mr. Larry Hogle, ARINC Research Corporation, "Evaluation of Various Navigation System Concepts"
1330	Question and answer period--open forum
1400	Round table discussion of certification issues--open forum
1600	Adjourn

Friday

September 17, 1982

0900	Review of minutes and corrections--chairman
0930	Briefing by Mr. Jim Savage, FAA Office of Flight Operations, Standards Development Branch (AFO-560), "Advisory Circular 90-45A and RTCA Special Committee 137"
1000	Question and answer period--open forum
1015	Round table discussion of certification issues--open forum
1200 - 1300	Lunch
1300	Briefing by Mr. Harold Downey, FAA Southwest Region, Airspace and Procedures Branch (ASW-538), "Report on the LORAN Flight Following (LOFF) Test at Houston Center"
1330	Question and answer period--open forum
1345	Round table discussion of problem areas--open forum
1600	Adjourn

Monday

September 20, 1982

0900	Review of minutes and corrections--chairman
0930	Briefing by Mr. Jerry Bradley, FAA Office of Systems Engineering Management, Requirements Definition and Integration Division (AEM-100), "The Federal Radio-Navigation Plan"
1000	Question and answer period--open forum
1015	Wrap-up of problem area identification--group members
1200 - 1300	Lunch
1300	Wrap-up (continued)--group members
1600	Adjourn

NATIONAL AIRSPACE REVIEW

Task Group 1-3 Routes

Scheduled Agenda

Tuesday

September 21, 1982

0900	Review of minutes and corrections—chairman
0930	Develop recommendations concerning random routes—group members
1200 - 1300	Lunch
1300	Develop recommendations (continued)—group members
1600	Adjourn

Wednesday

September 22, 1982

0900	Review of minutes and corrections—chairman
0930	Develop recommendations (continued)—group members
1200 - 1300	Lunch
1300	Complete recommendations—group members
1600	Adjourn

Thursday

September 23, 1982

0900	Review of minutes and corrections—chairman
1000	Begin review of recommendations—group members
1200 - 1300	Lunch
1300	Continue review of recommendations—group members
1600	Adjourn

Friday

September 24, 1982

0900	Review of minutes and corrections—chairman
1000	General discussion and closing remarks—group members
1200	Adjourn

SECTION 4

REMARKS OF
HARVEY B. SAFEER
DIRECTOR OF AVIATION POLICY AND PLANS
FEDERAL AVIATION ADMINISTRATION
AT THE
FUTURE NAVIGATION SYSTEM PLANNING CONFERENCE
ECONOMIC ISSUES IN NAVIGATION SYSTEMS PLANNING
WASHINGTON, D.C.
FAA AUDITORIUM
AUGUST 3, 1982

IT'S A PLEASURE FOR ME TO BE HERE THIS AFTERNOON TO DISCUSS ECONOMIC ISSUES CONCERNING NAVIGATION SYSTEMS PLANNING AND TO OUTLINE THE DEPARTMENT'S MODELING ACTIVITY WITH RESPECT TO NAVIGATION PLANNING. WE HAVE SPENT A GOOD PART OF THE DAY REVIEWING TECHNICAL ASPECTS OF NAVIGATION SYSTEMS AND THE VARIOUS NAVIGATION RESEARCH AND IMPLEMENTATION ALTERNATIVES UNDER CONSIDERATION BY THE DEPARTMENT OF TRANSPORTATION (DOT) AND THE DEPARTMENT OF DEFENSE (DOD). TOMORROW WE WILL COVER INSTITUTIONAL ISSUES AND DISCUSS PROCEDURES THAT DOT AND DOD PROPOSE TO FOLLOW IN MAKING A NATIONAL RECOMMENDATION CONCERNING THE MIX OF NAVIGATION SYSTEMS TO BE DEPLOYED DURING THE NEXT TWO DECADES.

ALTHOUGH ECONOMIC ISSUES ARE LISTED AS A SEPARATE TOPIC, THEY CANNOT READILY BE SEPARATED FROM TECHNICAL DESIGN CONSIDERATIONS, MOST INSTITUTIONAL ISSUES, THE FINAL DETERMINATION AS TO WHAT MIX OF SYSTEMS WILL BE CHOSEN, AND WHEN THEY WILL BECOME OPERATIONAL SYSTEMWIDE. ECONOMIC ANALYSIS IS ALSO REQUIRED TO DETERMINE WHAT LEVELS OF SERVICE ARE TO BE PROVIDED IN VARIOUS GEOGRAPHICAL AREAS. IN THAT RESPECT, ECONOMICS IS THE THREAD THAT TIES TOGETHER ENGINEERING DESIGN, INSTITUTIONAL ISSUES AND FINAL DEPLOYMENT DECISIONS. FOR EXAMPLE, A NAVIGATION SYSTEM DESIGN TYPICALLY EVOLVES THROUGH A SERIES OF DESIGN TRADEOFFS WHICH SIGNIFICANTLY AFFECT THE TOTAL COST OF A SYSTEM AND THE BALANCE OF COSTS BETWEEN THE PROVIDER AND USER STATIONS. IN THE CASE OF NAVIGATION, A CHANGE IN BALANCE SHIFTS COSTS BETWEEN THE GOVERNMENT AND USER COMMUNITY. IMPLEMENTATION OF A SYSTEM ALSO INVOLVES ECONOMIC TRADEOFFS WITH RESPECT TO RATE OF TRANSITION, SELECTION OF GEOGRAPHICAL AREAS FOR COVERAGE AND INDUSTRIAL PRODUCTION CAPABILITY. AN INSTITUTIONAL ISSUE SUCH AS WHO IS TO PAY FOR VARIOUS SERVICES GAINS IMPORTANCE AS THE PRICE OF SERVICE ESCALATES. ANOTHER IMPORTANT FACTOR IS THAT THE COST OF A SYSTEM BECOMES MORE PALATABLE WHEN THOSE WHO ARE PAYING FOR THE SYSTEM PERCEIVE THE BENEFITS ACCRUING TO THEM AS BEING AT LEAST EQUAL TO THE PRICE OF THE SERVICE BEING PROVIDED.

IN AVIATION, THE FEDERAL GOVERNMENT HAS BEEN RECOVERING A PORTION OF SERVICE COSTS FROM SYSTEM USERS SINCE 1970. PENDING LEGISLATION, IF ENACTED, WILL INCREASE THAT LEVEL OF COST RECOVERY. OTHER TRANSPORTATION MODES ARE ESTABLISHING COST RECOVERY GOALS. AS WE APPROACH FULL COST RECOVERY, USERS WHO ARE PAYING FOR SERVICES SHOULD EXPECT TO HAVE A HIGH LEVEL OF INFLUENCE ON DECISIONS CONCERNING THOSE SERVICES. AFTER ALL, IT IS THE USERS SYSTEM NOT OURS.

WE ALSO HAVE TO RECOGNIZE THAT THE NEEDS OF ALL SYSTEM USERS ARE NOT THE SAME. SOME CLASSES OF USERS MAY FIND SOPHISTICATED SYSTEMS TO BE VERY COST EFFECTIVE WHILE A LESS SOPHISTICATED SYSTEM USER WOULD HAVE A SUBSTANTIALLY LESSER REQUIREMENT. SHOULD WE BURDEN THIS LESS SOPHISTICATED USER WITH THE REQUIREMENT TO PURCHASE COSTLY EQUIPMENT?

THERE ARE THREE KEY ISSUES THAT WE MUST DEAL WITH BEFORE FINAL NAVIGATION SYSTEM RECOMMENDATIONS ARE MADE. DECISIONS ON EACH OF THESE ISSUES WILL BE HIGHLY INFLUENCED BY ECONOMIC CONSIDERATIONS. THEY ARE:

1. WHAT LEVEL OF NAVIGATION SERVICE IS ECONOMICALLY JUSTIFIED FOR VARIOUS GEOGRAPHICAL AREAS?

2. WHAT IS THE MOST ECONOMICAL MIX OF NAVIGATION SYSTEMS THAT WILL MEET THE DIVERSE REQUIREMENTS OF NATIONAL DEFENSE AND CIVIL AIR, MARINE AND POTENTIAL LAND USERS?

3. WHAT WILL BE THE OPTIMUM TIMING FOR TRANSITION FROM OUR EXISTING NAVIGATION SYSTEMS TO SELECTED FUTURE SYSTEMS?

WHEN THE FEDERAL AVIATION ADMINISTRATION (FAA) FIRST CONSIDERED THESE ISSUES WITH RESPECT TO AVIATION NAVIGATION IN THE MID TO LATE 1970'S WE DETERMINED THAT THE BEST WAY TO DEAL WITH THE SUBSTANTIAL NUMBER OF ALTERNATIVES, VOLUME OF DATA, AND VARYING PRICE STRUCTURES WAS TO TAKE ADVANTAGE OF AUTOMATED DATA PROCESSING TECHNIQUES. YOU MIGHT RECALL THAT THE "RAANS" MODELING ACTIVITY WAS REVIEWED AT THE <u>CONFERENCE ON NAVIGATION IN TRANSPORTATION</u> THAT WAS HELD IN CAMBRIDGE, MASSACHUSETTS IN SEPTEMBER 1978. THE OFFICE OF THE SECRETARY BELIEVED WE WERE ON THE RIGHT TRACK AND ASKED THAT THE RESEARCH AND SPECIAL PROGRAMS ADMINISTRATION (OR RSPA) DEVELOP A SIMILAR MODEL THAT WOULD CONSIDER ALL THREE MODES - AIR, MARINE AND LAND. OST ALSO REQUESTED THAT THE MODEL BE DESIGNED TO CONSIDER THE BENEFITS SIDE OF THE EQUATION. THE FAA ALONG WITH OTHER MODAL ADMINISTRATIONS HAVE BEEN PARTICIPATING IN RSPA'S DEVELOPMENT OF THE MODEL. AT FAA'S REQUEST THE AVIATION PORTION OF THE MODEL HAS BEEN DESIGNED TO ALSO ACCOMMODATE ANALYSIS OF SYSTEMS

OTHER THAN NAVIGATION. WE BELIEVE IT WILL BE A USEFUL TOOL TO ACCOMPLISH SIMILAR ANALYSIS FOR SOME ASPECTS OF OUR SURVEILLANCE AND COMMUNICATIONS SYSTEMS. THIS CAPABILITY WILL PERMIT US TO FINE TUNE OUR NAVIGATION ANALYSIS BY CONSIDERING SUCH SERVICES AS USING VOR'S AS COMMUNICATIONS OUTLETS TO BROADCAST WEATHER INFORMATION.

THE DEPARTMENT OF DEFENSE IS WORKING ON A NAVIGATION SYSTEM ANALYSIS THAT IS SIMILAR TO OURS. IT IS BEING CLOSELY COORDINATED AT THE DEPARTMENT LEVEL. THE SECRETARIES OF TRANSPORTATION AND DEFENSE PLAN TO MAKE A PRELIMINARY JOINT RECOMMENDATION CONCERNING NAVIGATION SYSTEMS IN 1983 AND A FINAL RECOMMENDATION IN 1986.

DURING JUNE WE BEGAN VALIDATION TESTING OF THE MULTI MODAL MODEL. THE TESTING INCLUDED DEVELOPMENT AND RUNNING OF A RANGE OF NAVIGATION SCENARIOS. THE PRELIMINARY RESULTS ARE PROVIDING SOME INTERESTING INSIGHTS INTO POTENTIAL USER AND GOVERNMENT COST IMPACTS. I SHOULD EMPHASIZE THAT THESE RESULTS ARE PRELIMINARY AND A SUBSTANTIAL AMOUNT OF ADDITIONAL WORK NEEDS TO BE DONE IN REFINING SCENARIOS, SENSITIVITY TESTING AND VARYING TRANSITION PERIODS. WE ALSO NEED TO REVIEW AND REFINE BENEFIT ASSESSMENTS THAT ARE JUST NOW BEGINNING TO BECOME AVAILABLE.

WE HAVE TESTED SEVERAL SCENARIOS. FOUR OF THESE COVER OUR PRIMARY INTERESTS. THE FOUR SCENARIOS RANGE FROM (1) AS A BASELINE, MAINTAINING OUR EXISTING MIX OF SYSTEMS, (2) REPLACING VOR/DME WITH LORAN C, (3) REPLACING ALL NON-PRECISION NAVIGATION SYSTEMS WITH GPS, AND (4) REPLACING ALL NON-PRECISION NAVIGATION SYSTEMS WITH GPS BUT RETAINING VOR/DME FOR LOW COST AIRCRAFT.

IN WORKING TOWARDS OUR INITIAL RECOMMENDATIONS WE ARE CONSIDERING BOTH AIR AND MARINE NAVIGATION SYSTEMS. THIS IS BECAUSE THE FAA AND THE COAST GUARD ARE THE MAJOR PROVIDERS OF NAVIGATION SERVICES AND THE AVIATION SECTOR IS MAKING INCREASING USE OF COAST GUARD PROVIDED NAVIGATION SERVICES. THE EXECUTIVE BRANCH OF THE GOVERNMENT BELIEVES THAT SYSTEM USERS SHOULD PAY FOR THE SERVICES PROVIDED. THE USER SUPPORTED AVIATION TRUST FUND HAS PROVIDED FUNDS FOR ALL OUR AVIATION FACILITY INVESTMENTS AND SOME OF OUR OPERATIONS COSTS FOR OVER A DECADE. FAIRNESS WOULD DICTATE THAT WITHIN THE TIMEFRAME BEING CONSIDERED FOR TRANSITION TO OTHER NAVIGATION SYSTEMS THAT COSTS WILL ALSO BE RECOVERED FROM MARINE USERS. WE ARE NOT CONSIDERING THE LAND MODE AT THIS TIME BECAUSE THE LAND MODE IS NOT CURRENTLY PROVIDING ANY NAVIGATION SERVICES, NOR ARE THEY EXPECTED TO IN THE FUTURE. ANOTHER IMPORTANT

CONSIDERATION IS THAT AT PRESENT THERE ARE VIRTUALLY NO LAND USERS OF EXISTING NAVIGATION SERVICES AND PREDICTION OF FUTURE LAND MODE USAGE OF NAVIGATION SERVICES IS VERY SPECULATIVE.

UNDER THE CONCEPT OF ALL SYSTEM USERS PAYING THEIR FAIR SHARE WE CAN THINK IN TERMS OF MINIMIZING TOTAL SYSTEM COSTS. BY TOTAL I MEAN BOTH GOVERNMENT AND USER LIFE CYCLE COSTS. I AM SURE THAT AS THE ANALYSIS PROCEEDS EACH OF YOU WILL SEE A SCENARIO WHICH MINIMIZES THE COST TO YOU OR YOUR CONSTITUENTS. SUCH SUB-OPTIMIZATION MAY BE WARRANTED DEPENDING UPON THE DISTRIBUTION OF SYSTEM BENEFITS. WE WILL BE INVESTIGATING THESE ALTERNATIVES AS WELL AS SYSTEM OPTIMIZATION ALTERNATIVES.

THE FOUR SCENARIOS WE'LL BE DISCUSSING HAVE BEEN NUMBERED 1, 100, 200 AND 201 ON THE VIEWGRAPHS. THEY ARE FIRST CUTS AT AN ANALYSIS AND ARE BEING PRESENTED TODAY AS EXAMPLES OF THE ANALYTICAL CAPABILITY WHICH THE DEPARTMENT HAS DEVELOPED. WE WOULD BE INTERESTED IN ANY SCENARIOS WHICH YOU MAY PROPOSE.

SCENARIO 1 WE CALL THE BASELINE SCENARIO. IN THIS SCENARIO CURRENT NAVIGATION SYSTEMS CONTINUE TO OPERATE AND PROVIDE SERVICES IN THE SAME GEOGRAPHICAL AREAS AS THEY NOW DO. IN OTHER WORDS, VOR/DME PROVIDES THE PRIMARY CONUS AND ALASKA AVIATION NAVIGATION SERVICE. SYSTEM USERS IN OCEANIC AREAS RELY ON OMEGA, OFFSHORE AVIATION USERS AND OTHERS WHO HAVE SPECIAL NEEDS RELY ON LORAN C IF VOR/DME SERVICE IS NOT AVAILABLE.

IN SCENARIO 100 LORAN C REPLACES VOR/DME WITH A TEN YEAR TRANSITION BETWEEN 1990 AND 2000. IN THIS SCENARIO, OMEGA SUPPLEMENTS THE EXPANDED LORAN C SYSTEM FOR THOSE AREAS WHERE THERE IS NO LORAN C COVERAGE. THE FAA BEARS THE BURDEN OF COST FOR ADDITIONAL LORAN C STATIONS REQUIRED FOR CIVIL AIR NAVIGATION.

IN SCENARIO 200, GPS REPLACES ALL OTHER RADIO NAVIGATION SYSTEMS WITH A TEN YEAR TRANSITION BETWEEN 1990 AND 2000. IN THE YEAR 2000 ALL OTHER SYSTEMS WOULD BE TURNED OFF WITH GPS BEING THE SOLE REMAINING CIVIL AVIATION RADIONAVIGATIONAL SYSTEM - EXCEPT FOR PRECISION LANDING SYSTEMS WHICH WILL CONTINUE TO BE GROUND BASED. THE FAA PAYS FOR SIX GPS SATELLITES REQUIRED TO INCREASE THE NUMBER OF DOD FURNISHED SATELLITES FROM 18 TO 24. FAA TECHNICAL ANALYSIS HAS INDICATED THAT 24 SATELLITES WOULD BE REQUIRED FOR ADEQUATE AVIATION SERVICE.

SCENARIO 201 IS A MODIFICATION OF SCENARIO 200. IN THIS SCENARIO GPS IS DEPLOYED BUT VOR/DME IS NOT DECOMMISSIONED AND THE RESPECTIVE AVIATION USERS SELECT THE EQUIPMENT THAT IS LEAST COSTLY TO MEET THEIR REQUIREMENTS. THE FAA AND THUS THE AVIATION USER BEARS THE ADDITIONAL COST OF SIX GPS SATELLITES AND MAINTENANCE AND OPERATION OF THE VOR/DME SYSTEM.

(V-1) THIS VIEWGRAPH PRESENTS A COST COMPARISON BETWEEN THE FOUR SCENARIOS. THE COSTS SHOWN ARE IN 1981 DOLLARS - UNDISCOUNTED AND UNINFLATED. THE BAR CHARTS SHOW SOME INTERESTING RELATIONSHIPS. THE MOST OBVIOUS IS THAT THE USER COMMUNITY NAVIGATION EQUIPMENT INVESTMENTS WILL PROBABLY EXCEED BY A FACTOR OF FIVE INVESTMENTS BY THE CIVIL GOVERNMENT. ANOTHER INTERESTING FACTOR IS THAT AVIATION USER COSTS WILL EXCEED MARINE USER COSTS BY A FACTOR OF ABOUT TEN. WHEN CONSIDERING NAVIGATION COSTS IT IS CLEAR THAT AVIATION WILL REMAIN THE DOMINANT FORCE.

WE FIND THAT WHEN TOTAL COSTS ARE CONSIDERED, THE MOST EXPENSIVE OPTION FOR THE CIVIL SECTOR WOULD BE THE GPS TRANSITION SCENARIO - 200. WITHOUT ACCOUNTING FOR INFLATION TOTAL COST WOULD BE ABOUT $16.4 BILLION DURING THE 1981 THROUGH 2005 TIMEFRAME. THE TOTAL COSTS FOR THE BASELINE CURRENT SYSTEM MIX SCENARIO (1) AND SCENARIO 201 - GPS WITH CONTINUED VOR/DME SERVICE FOR LOW COST AIRCRAFT ARE ABOUT EQUAL - $14.8 BILLION. HOWEVER, THERE IS AN INTERESTING SHIFT IN BALANCE OF COSTS BETWEEN GOVERNMENT AND USERS IN THESE TWO SCENARIOS. IN SCENARIO 1 GOVERNMENT COSTS ARE LOWER BY ABOUT $900 MILLION WHILE USER COSTS ARE HIGHER BY ABOUT $900 MILLION DOLLARS. THERE IS A CLEAR TRADEOFF BETWEEN GOVERNMENT AND USER COSTS IN THESE TWO SCENARIOS. TRANSITION TO GPS ONLY, WILL HAVE THE GREATEST IMPACT ON THE GA COMMUNITY. IN THIS CASE THE COST TO AVIATION USERS WOULD INCREASE BY ABOUT $1.1 BILLION WHILE THE COST TO MARINE USERS WOULD INCREASE BY LESS THAN $200 MILLION.

(V-2) ECONOMISTS LIKE TO CONSIDER THE TIME VALUE OF MONEY IN THEIR DECISIONMAKING. THEREFORE, WE ARE ALSO LOOKING AT OUR COSTS DISCOUNTED AT THE TEN PERCENT RATE PRESCRIBED BY THE OFFICE OF MANAGEMENT AND BUDGET FOR CONDUCTING ECONOMIC ANALYSIS IN THE TRANSPORTATION SECTOR.

USING THIS PRESENT VALUE TECHNIQUE WE FIND THAT THE TOTAL COSTS ARE LOWEST IF WE CONTINUE WITH OUR BASELINE SYSTEM MIX. TOTAL COSTS FOR THAT SCENARIO FOR THE 1981 THROUGH 2005 WOULD BE ABOUT $5.2 BILLION, WHILE THE NEXT BEST, SCENARIO 201, IS ABOUT $0.2 BILLION MORE COSTLY. THE HIGHEST COST SCENARIO WOULD STILL REMAIN THE GPS ONLY SCENARIO 200, WITH A COST DIFFERENCE, WHEN COMPARED TO THE BASELINE MIX, BEING ABOUT A HALF A BILLION DOLLARS.

(V-3) THERE IS ANOTHER SET OF CONSIDERATIONS WE'RE LOOKING AT - THE AVIONICS COST DISTRIBUTION FOR VARIOUS CLASSES OF AVIATION USERS. WE HAVE THE CAPABILITY OF CONSIDERING SEPARATELY THE COSTS TO AIR CARRIERS, COMMUTERS, AIR TAXI OPERATORS, EXECUTIVE/BUSINESS, PERSONNEL USE AND PUBLIC USE AIRCRAFT. ALGORITHMS WITHIN THE MODEL ASSIGN AVIONICS TO FORECASTED POPULATIONS OF AIRCRAFT BASED UPON TYPE OF AIRCRAFT, GEOGRAPHICAL AREA OF OPERATION AND NAVIGATION SERVICE AVAILABLE IN THAT AREA. WE HAVE DEFINED FOUR CLASSES OF AVIONICS--FROM THE MOST SOPHISTICATED THAT IS NORMALLY PURCHASED BY THE AIR CARRIER COMMUNITY TO THE LEAST SOPHISTICATED THAT MIGHT BE PURCHASED FOR A LOW COST GENERAL AVIATION AIRCRAFT. WE HAVE ALSO DEFINED REDUNDANCY REQUIREMENTS. THE PRICE OF EACH CLASS OF RECEIVER VARIES WITH TOTAL PRODUCTION QUANTITIES AND A TECHNOLOGY IMPROVEMENT FACTOR THAT VARIES WITH TIME. FOR EXAMPLE AN AIR CARRIER DUPLICATE VOR/DME WITH 2D RNAV CAPABILITY THAT COST $90 THOUSAND IN 1981 WOULD BE PRICED AT ABOUT $22 THOUSAND IN 2005. SIMILARILY A LOW COST VOR RECEIVER THAT WAS AVAILABLE FOR $1,400 IN 1981 WOULD BE PRICED AT ABOUT $400 DOLLARS IN 2005. AS I SAID BEFORE, THESE FIGURES ARE NOT INFLATED, BUT PRODUCTION QUANTITIES AND TECHNOLOGY IMPROVEMENTS ARE ACCOUNTED FOR.

THE DOMINANT FEATURE ON THIS BAR CHART IS THE AVIONICS EXPENDITURES OF THE GENERAL AVIATION COMMUNITY. THIS GROUP CONSISTS OF THE EXECUTIVE/BUSINESS AND PERSONAL USE CLASSES. IN GENERAL, THE EXECUTIVE/BUSINESS CLASS CONSISTS PRIMARILY OF TURBO JET, MULTI-ENGINE PISTON, AND TURBO PROP AIRCRAFT. THE PERSONAL CATEGORY CONSISTS MAINLY OF SINGLE ENGINE PISTON AIRCRAFT.

AS I MENTIONED BEFORE, THE LOWEST COST SCENARIO FOR AVIATION USERS IS SCENARIO 201, GPS AND VOR/DME UNDER THIS SCENARIO AVIONICS COSTS WOULD BE ABOUT $1.1 BILLION LESS THAN THE BASELINE MIX SCENARIO. AVIONICS COSTS WOULD BE LOWER FOR ALL CLASSES OF USERS. THE MOST COSTLY SCENARIO WOULD BE THE TRANSITION TO GPS ONLY, WHICH WOULD REQUIRE ABOUT $0.7 BILLION MORE IN AVIONICS COSTS THAN THE BASELINE. UNDER EACH OF THE SCENARIOS THE COST DIFFERENCES FOR AIR CARRIERS, COMMUTERS, AIR TAXI AND PUBLIC USE WOULD BE RELATIVELY UNIMPORTANT. THERE WOULD BE SIGNIFICANT DIFFERENCES FOR THE BUSINESS AND PERSONAL CATEGORIES.

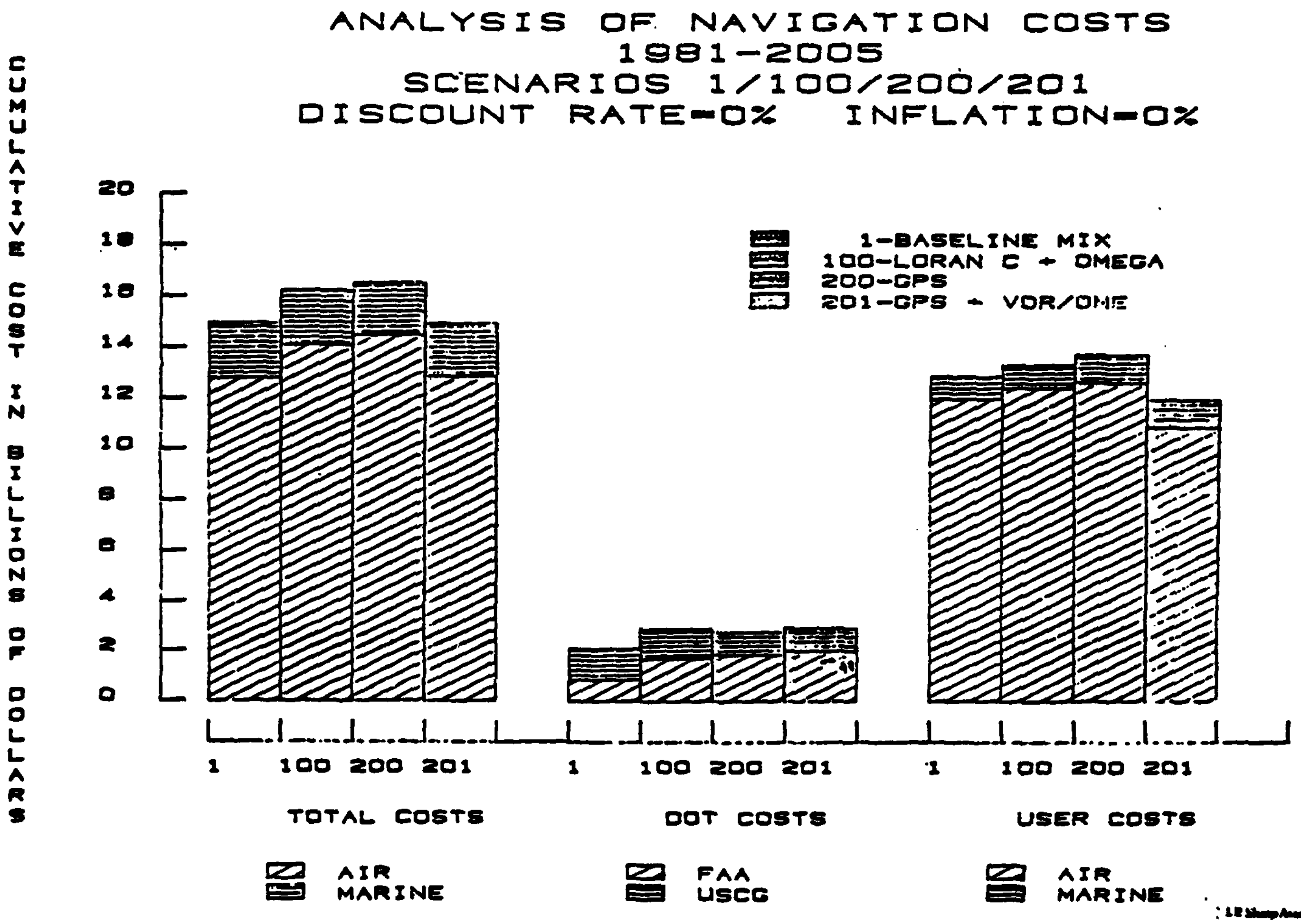
FOR BUSINESS FLYERS THE BASELINE MIX WOULD PROVE TO BE THE MOST COSTLY OPTION. THE ABILITY TO CHOSE BETWEEN GPS AND VOR/DME WOULD GIVE THIS GROUP THE BEST ADVANTAGE. FOR THE PERSONAL FLYER THE BASELINE OPTION AND THE GPS/VOR/DME OPTION WOULD PROVIDE ABOUT A $1.3 BILLION ADVANTAGE OVER BOTH THE

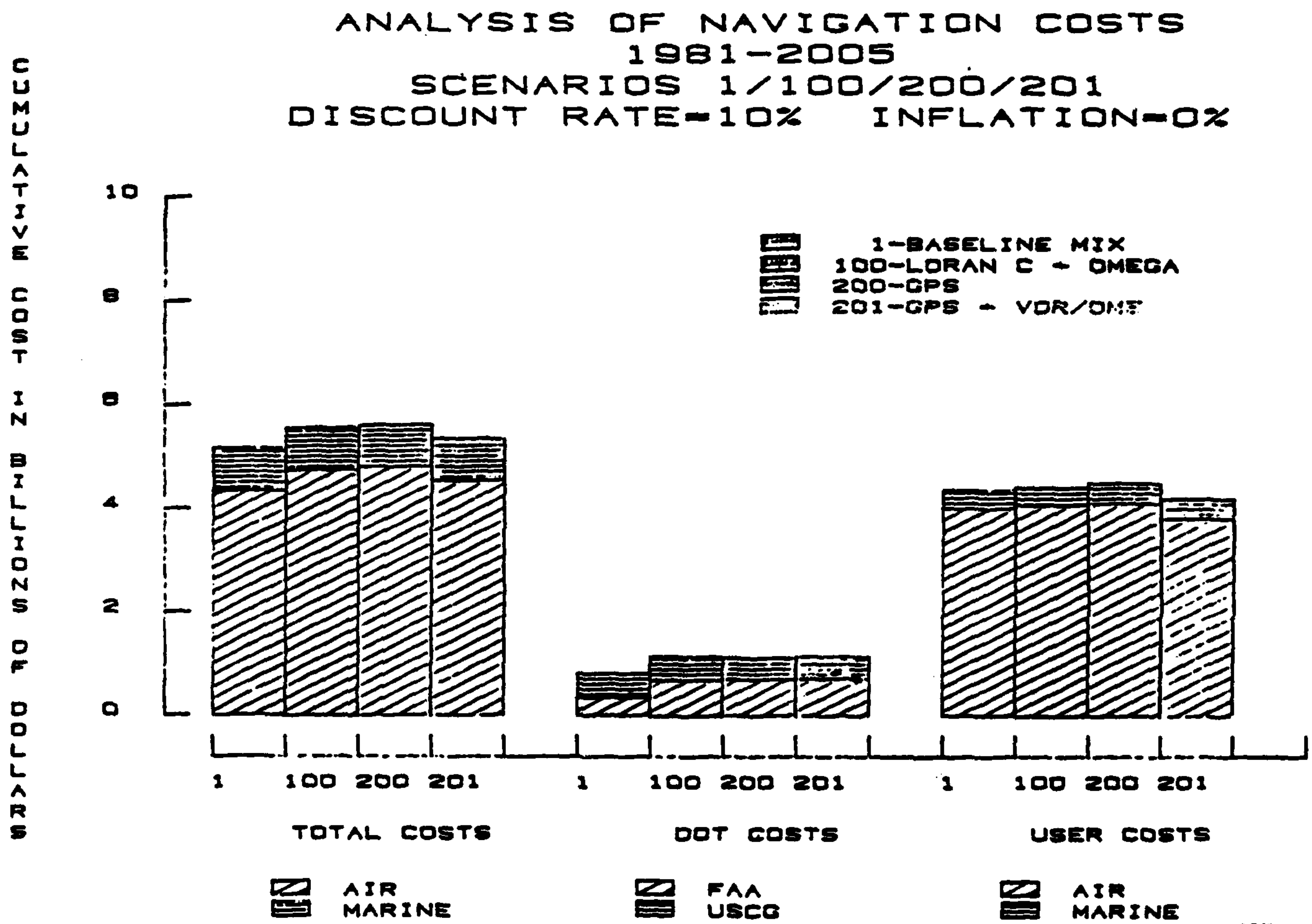
LORAN C/OMEGA AND GPS OPTIONS. FROM AN ECONOMIC STANDPOINT NAVIGATION DECISIONS WILL HAVE THEIR MAIN IMPACT ON THE GENERAL AVIATION COMMUNITY.

(V-4) FROM THE PRESENT VALUE PERSPECTIVE, ALL OF THE BASIC RELATIONSHIPS DISCUSSED UNDER UNDISCOUNTED CONDITIONS REMAIN THE SAME. AS EXPECTED, THE INDIVIDUAL COSTS ARE SIGNIFICANTLY REDUCED IN MAGNITUDE DUE TO DISCOUNTING.

FROM A COST PERSPECTIVE, OUR PRELIMINARY WORK HAS SHED CONSIDERABLE LIGHT ON BOTH GOVERNMENT AND USER IMPACTS. OVER THE NEXT FEW MONTHS, WE WILL BE LOOKING AT REFINEMENTS TO THE BASIC SCENARIOS WE HAVE TESTED. WE ALSO PLAN TO DO SENSITIVITY CHECKING WITH RESPECT TO SYSTEM COSTS, AVIONICS COSTS, AND TRANSITION TIMES. ONCE AGAIN LET ME INVITE YOU TO SUGGEST SCENARIOS WHICH MAY ADD RELEVANT INPUT TO THE FINAL RECOMMENDATIONS.

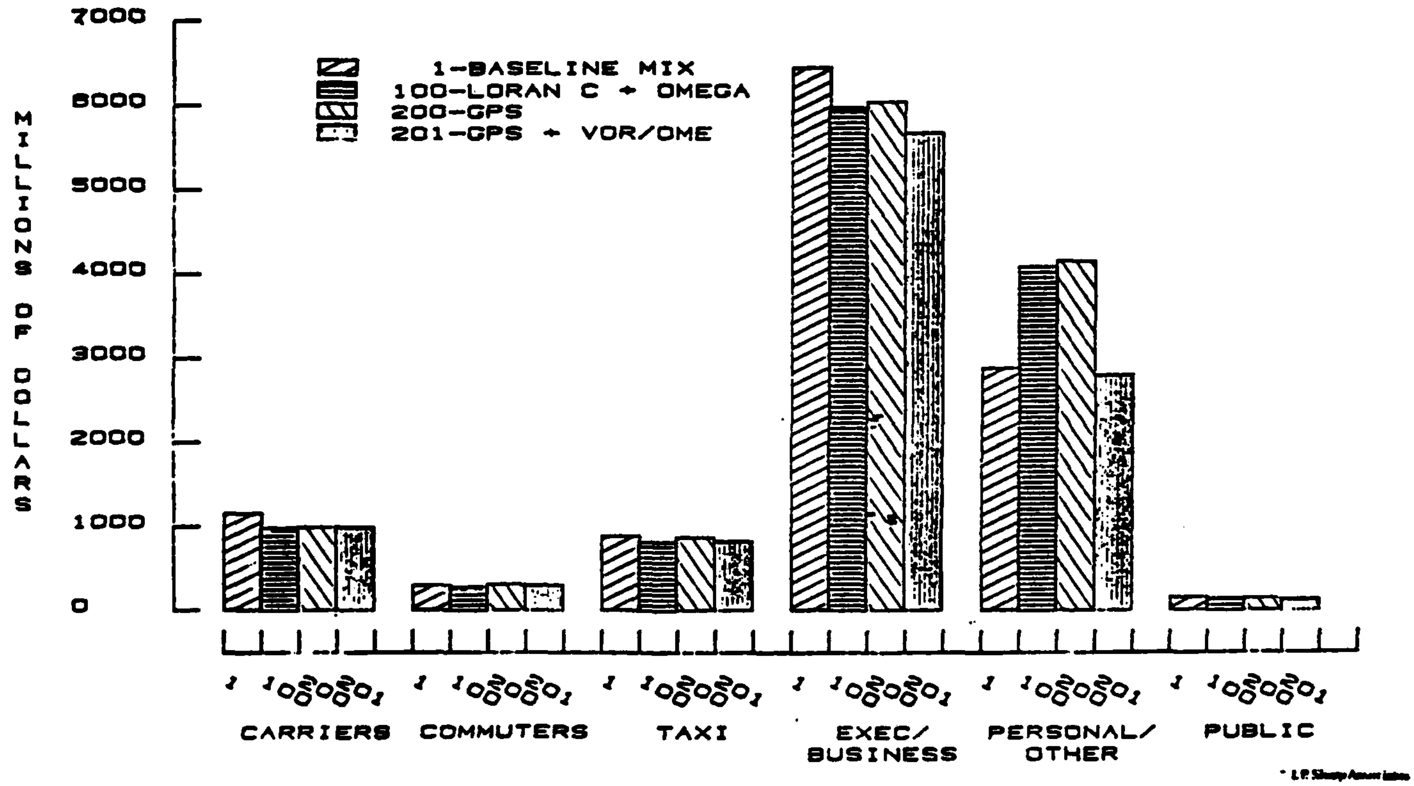
BEFORE MAKING PRELIMINARY RECOMMENDATIONS TO THE SECRETARY CONCERNING THE MIX OF FUTURE NAVIGATION SYSTEMS, THE REFINED ECONOMIC ANALYSIS WILL BE WEIGHED AGAINST TECHNICAL AND INSTITUTIONAL CONSIDERATIONS. IT IS CLEAR THAT BEFORE FINAL RECOMMENDATIONS ARE MADE, TECHNOLOGY MUST BE PROVEN, INSTITUTIONAL ISSUES RESOLVED AND A REASONABLE BALANCE ESTABLISHED BETWEEN GOVERNMENT COSTS WHICH ARE INDIRECTLY PAID BY THE USER THROUGH USER TAXES AND THE DIRECT COST TO VARIOUS USERS FOR ON BOARD AVIONICS.


ANALYSIS OF NAVIGATION COSTS
1981-2005
SCENARIOS 1/100/200/201
DISCOUNT RATE=0% INFLATION=0%
CUMULATIVE COST IN BILLIONS OF DOLLARS
20
18
16
14
12
10
8
6
4
2
0
1-BASELINE MIX
100-LORAN C + OMEGA
200-GPS
201-GPS + VOR/DME
1 100 200 201
TOTAL COSTS
DOT COSTS
USER COSTS
AIR
MARINE
FAA
USCG
AIR
MARINE



ANALYSIS OF NAVIGATION COSTS
1981-2005
SCENARIOS 1/100/200/201
DISCOUNT RATE=10% INFLATION=0%
CUMULATIVE COST IN BILLIONS OF DOLLARS
10
8
6
4
2
0
1-BASELINE MIX
100-LORAN C + OMEGA
200-GPS
201-GPS + VOR/DME
1 100 200 201
TOTAL COSTS
1 100 200 201
DOT COSTS
1 100 200 201
USER COSTS
AIR
MARINE
FAA
USCG
AIR
MARINE

AVIATION USER NAVIGATION COSTS
CUMULATIVE CASH OUTLAY 1981-2005
DISCOUNT RATE=0% INFLATION=0%



SECTION 5

REMARKS OF S. B. PORITZKY
DIRECTOR OF SYSTEMS ENGINEERING MANAGEMENT
FEDERAL AVIATION ADMINISTRATION

FUTURE NAVIGATION SYSTEMS PLANNING CONFERENCE
WASHINGTON, D.C.
AUGUST 3, 1982

When all the other issues have been dealt with--technical capability, operational suitability, and costs--there remains a series of issues we have labeled as "institutional." They deal with control of signal access and accuracy, international standardization, and cost recovery. And one more which, in the end, may be the toughest--transition.

There are lots of questions and no clear answers to these issues, but I'd like to describe some of them to provoke your reactions.

First is the question of control of signal access and of accuracy. NAVSTAR/GPS, at present, is planned to be under the control of the U.S. military and, thus, its service is subject to removal when a U.S. national emergency dictates. Unlike systems such as VOR/DME and LORAN-C which cover only a relatively small geographic area, NAVSTAR/GPS covers large masses of the earth's surface, and any decision to remove one or more of those facilities, either by the U.S. or by an unfriendly power, would have impact in this country and far beyond. Similar systems which might be offered by others would have like problems.

Will some civil aviation elements feel that no system which is to provide service beyond national borders is acceptable if the signal is subject to removal on the grounds of security concerns of a single State or group of States?

In civil systems, and especially in systems which have achieved international standardization, Administrations deliberately strive to provide service with high reliability and with the best performance of which the system and the maintenance infrastructure are capable. Will some believe that no system is acceptable which is subject to artificial reduction of its performance?

On the other side of the coin, DOD has always had the power to take control of all navigation services in time of national emergency, yet such power has never, to our knowledge, been exercised. Further, LORAN-A in the past, Transit, and the U.S. Navy VLF communication stations used in conjunction with OMEGA, are in fact in wide use internationally by civil users without such assurances.

There is a dilemma here. Formal positions and actual practices have differed widely, related in no small way to the charges levied on, or expected by, the users of the system. And, aside from the international departure tax, the U.S. does not now charge non-U.S. users of U.S. systems.

A related issue is the basic problem of systems whose coverage is so broad that failure of one or two elements can remove service from a large geographic area. NAVSTAR/GPS and OMEGA fall in this category. There is not much argument that such

systems are more vulnerable than others. Is there safety in numbers of lesser-coverage ground systems, or is that an archaic view in 1990?

If worldwide systems like NAVSTAR/GPS are operated and controlled by one State, the question of cost recovery becomes important. For a U.S. system, it is reasonably easy for us to recover costs from domestic users, but going beyond our shores would surely require a multilateral or a worldwide agreement, and almost certainly international standardization as a first step.

One approach to cost recovery, offered in a recent study done for DOD, would be to sell keys for the use of the system. The keys, which would make the airborne receiver work, would be changed annually so that user charges could be collected at the time of their purchase. But that method would appear to be difficult to administer or reach agreement on internationally. Equally important, such a process would, in fairness, have to be considered for other services as well.

As Mr. Helms noted, it would be easier to achieve standardization of a system like NAVSTAR/GPS if it were a civil system under control of the civil administration, but better yet if it were a truly international venture, under international sponsorship.

A related question with respect to NAVSTAR/GPS is the burden on the civil user of buying a system more complex than it needs to be because of the need to meet military requirements. Cost sharing formulas for the government part of the system could of course be worked out, but that may be insufficient comfort to the owner of a small general aviation aircraft who is asked to pay for avionics complexity he doesn't need.

There is yet another question to be considered, which applies to both OMEGA and NAVSTAR/GPS. Military needs change far more rapidly than civil ones, and for very sound reasons. But now suppose that NAVSTAR/GPS, the more expensive of the two, is accepted by the civil community because it makes sense on a reasonable cost-sharing basis; and ten years from now, or fifteen, there is no longer a military need, and therefore no motivation for DOD to continue support. Should the civil community make its cost assessment on the basis of expected continued cost sharing with DOD, or must we assume that some years hence, the system must be justifiable, and paid for, by civil users only? Is it perhaps reasonable to assume that, since satellites have limited life, the system could be compatibly transformed, if and when the time comes, into an optimized civil system?

One of the questions posed by Mr. Helms deals specifically with the desirability of achieving a single universal navigation system, as opposed to a relatively small mix of systems which serve particular uses. That question has two aspects: It has already been noted, looking at aviation's needs alone (once again excluding precision approach and landing guidance), that NAVSTAR/GPS looks capable of meeting all future requirements. Neglecting problems of transition, in the long run only the small general aviation user would be asked to pay more. A mix of NAVSTAR/GPS and VOR/DME can resolve the small general aviation user's problem, but the taxpayers and users would now pay for the provision of both NAVSTAR/GPS and VOR/DME. Do we conclude that there is in reality a tangible benefit to moving toward a single universal navigation system as opposed to a mix?

The picture changes somewhat when we look at the broader needs for navigation in the Nation as a whole--or the world. If we include maritime users and, potentially, land users as well, GPS appears even more attractive. Yet, when we count user noses for the foreseeable future, maritime users who use complex navaids may be only a moderate percentage of civil users, considering the large general aviation fleet. Finally, while cost recovery schemes for aviation users in the U.S. and across the world are well developed, the same is not true for cost recovery from maritime users.

The problems of international standardization are great for any new system, even if there are few institutional issues. The process is lengthy and complicated. It is necessary for the States of ICAO to perceive a real need for the new service. They must perceive that there is clear and obvious benefit to them and their aircraft from the transition, and that the technology is available to permit manufacture across the world.

NAVSTAR/GPS, or any worldwide satellite-based system viewed in international terms, has a significant benefit. Many States may not need to provide any ground services to achieve system coverage. Especially in the developing world, paying for the use of such services may be preferable to undertaking a major implementation program of ground facilities.

Finally, the question of transition. All transitions are painful because they almost never can be timed to the benefit of all users. Duplicate services must be provided, often for a long time, in order to make the transition sufficiently painless to be acceptable. Costs for the provision of duplicate services have to be borne by both Administrations and users during the transition. The attractiveness and benefits of new systems must be beyond dispute before the world community will engage in such a transition.

The issues I have discussed have dealt only with navigation services. The picture is not the same if we consider a new satellite system which may provide navigation along with surveillance and data link communications. If we believe that is the proper direction for the future, a whole new list of issues and possibilities emerges.

As you see, there are several vexing questions. I hope that later in this session you will discuss your thoughts and the conclusions you reach.

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SECTION 6

COMMENTS BY EXPERTS PANEL

Several recognized experts were invited to present their views on future navigation system planning as a panel during the conference. They also addressed various issues identified at the conference, particularly the five questions posed by the Administrator. Although formal papers were not requested of the panel members for their presentations at the conference, papers summarizing their remarks were requested for the proceedings and are included in the following pages. The invited navigation system experts who participated on the conference panel with their affiliation are listed below:

Mr. Frank B. Brady
Executive Director, Institute of Navigation

Mr. Sven H. Dodington
Avionics Consultant, International Telephone and Telegraph Corporation

Mr. Edward J. King
Chairman of the Board, King Radio Corporation

Mr. John W. Klotz
Aviation Consultant

Mr. Harry Sonnemann
Deputy Chief Engineer, National Aeronautics and Space Administration

Mr. Alexander B. Winick
Aviation Consultant

FRANK H. BRADY
EXECUTIVE DIRECTOR
INSTITUTE OF NAVIGATION

1. Maintaining the status quo on domestic and international navigation systems would appear to satisfy future aviation navigation requirements with the least possible disruption and at minimum initial cost to users. This, however, may not be the most desirable course of action when other major user requirements are considered or when long term cost effectiveness is a factor.

2. With the dramatic downward trend in computation costs it should not be too much to ask even the minimum equipped aircraft to include area NAV capability by the turn of the century. A steady improvement in VOR/DME accuracy should be a natural fallout of FAA's ongoing maintenance improvement program. Low altitude coverage can probably be provided where needed rather than on a general coverage basis.

3. The benefits of a complete transition to a more universal navigation system such as GPS are not fully clear at this time and it will undoubtedly take an extended period during which both systems are carried by some users before a clear cut determination can be made.

4. If military requirements of GPS are such that only a small share of the cost of the system would be borne by civil users then GPS as the sole future radionavigation system would be attractive provided the GPS system lives up to its claims and provided civil users are given access to the full accuracy capabilities of the satellite system.

5. It is very late in the game to consider an expanded service satellite navigation system which might also include ATC surveillance and digital communication capability. However, I believe it is worthwhile to study the feasibility of additional capabilities from satellite systems. This study should focus on compatability of the added services and should pay particular attention to fall back capabilities. We've always had independent redundancy in airways facilities and the "all or nothing" aspect of integrated navigation, communication and surveillance in our ATC system is something that requires careful consideration.

SVEN H. DODINGTON
AVIONICS CONSULTANT
INTERNATIONAL TELEPHONE AND TELEGRAPH CORPORATION

Ladies and Gentlemen: Before I start, let me first make a disclaimer: ITT has no particular commercial axe to grind in this discussion. In one way or another, we have been, or are currently, involved in all the systems covered by the Federal Radionavigation Plan. For example, on VOR/DME we are the principal contractor in the FAA upgrade program: on OMEGA we built the earliest Navy receivers and tried hard to generate civil interest, apparently a decade too early; on LORAN-C we built much of the existing equipment and are currently installing two chains in Saudi Arabia; on GPS, we are a major subcontractor on the satellites and, in the UK, we have just delivered the first airborne receivers built outside the U.S.

What I have to say represents my own personal opinion. First, four points of my own, then answers to Mr. Helms' five questions.

1. We cannot rely on a single system, to replace all others. A single system goes against the grain of all practical navigation, both civil and military. A minimum of two, preferably independent, systems is a definite requirement, under all conditions. In the military, this may well be GPS and INS, but such a combination is far too expensive for the average civil user. VOR/DME is backed by its own redundancy of stations, plus NDB/ADF.

2. In comparing the costs of the various systems, I would be much happier if the DOT would concentrate on just the cost of providing the signal-in-space, and not muddy the water by dragging in the cost of the airborne hardware. This latter cost is a function of the marketplace and does not involve the taxpayer. Currently, you can spend between $5,000 and $60,000 for a TACAN set, and between $1,000 and $20,000 for a LORAN-C set. I defy any federal bureaucrat to keep track of what this means to "user costs," particularly over the next twenty years. Furthermore, I do not see Lincoln Lab as an appropriate arbiter of what a general-aviation receiver should cost. If we just look at the cost of maintaining the systems under discussion, today's figures appear to be:

VOR/DME	$ 30 million/yr.
OMEGA	$ 8 million/yr.
LORAN-C	$ 30 million/yr.
GPS	250 million/yr.

These are the sums to be paid by the U.S. taxpayer to maintain the respective signals-in-space. What the user then does with those signals is strictly his own business.

3. Let's not be too hasty in giving up the rho-theta concept. It is the only system that defines aircraft location from a single ground station, which can be installed on land, on an island, on a ship or an oil-platform. It is the result of 40 years of international cooperation and is backed by some 100 civil administrations and dozens of military administrations, not just in NATO, but also elsewhere (e.g. there are 23 TACAN beacons in Saudi Arabia, 40 in Japan). It is modular, allowing growth from the simple VOR to VOR/DME, VORTAC and DME/DME.

I have not heard of a single administration, now using the ICAO rho-theta system, who would willingly give it up in favor of a satellite system run by a foreign government.

4. We did not hear much yesterday about vulnerability, but it has been of much concern to some of us, whether due to equipment failure, sabotage or enemy action. The number of stations in the world currently looks like this:

NDB	4500
VOR/DME	2000
OMEGA	8
LORAN-C	50
GPS	24 satellites, 1 upload

There is "safety in numbers," if nothing else.

5. Mr. Helms' five questions:

1. No. I see no real need to change the present mix of NDB, VOR/DME, OMEGA and LORAN-C.

2. No. "Precision-VOR" was looked at 20 years ago and abandoned because it required new airborne equipment. A few extra VOR's to provide better coverage in mountainous terrain may be justified, but will never do the whole job.

3. No. For reasons already given.

4. No. For reasons already given.

5. If we could get a cheaper satellite system, with international agreement, I would favor more work on satellite systems. But I am skeptical that much would come of it.

Thank you.

EDWARD J. KING, JR.
CHAIRMAN OF THE BOARD
KING RADIO CORPORATION

A great deal of time and effort has been expended to analyze merits of existing, developmental and conceptual navigation systems for economically meeting perceived domestic and international needs for the next 20 years and beyond. This conference has been focusing on VOR/DME, TACAN, OMEGA/VLF, LORAN-C and NAVSTAR/GPS. Some organizations have suggested that we should be considering alternatives such as ASTRODABS/MODE-S or Dr. Gerard K. O'Neill's "TRIAD" system described in the July 1982, issue of Pilot Magazine.

After all of the technical analyses, "user cost/benefit" studies and distribution of stacks of printed material, are we really ready to move ahead and make decisions?

I perceive that each system has technical, political and economic strengths and weaknesses.

VOR/DME and TACAN have served us extremely well and can do even better in the future. With data base systems and other enhancements, airborne VORTAC-based systems will offer economical long-range navigation in our domestic airspace. However, line-of-sight/range limitations, inability to navigate over the oceans, absence or scarcity of stations in many regions of the world are important restrictions. VOR/DME and TACAN are internationally recognized and developed and we should remember that the destinies of VOR and localizer are somewhat intertwined since both airborne equipments share a common receiver.

LORAN-C offers excellent repeatability and with appropriate propagation, anomally correction, it offers good accuracy at ranges up to 900 miles from the most distant master or slave station in use. The system typically operates at low signal to noise ratios and is vulnerable to atmospheric noise. LORAN-C has been touted as an appropriate NAVAID for airports in difficult mountainous terrain such as Vermont, or the Western Mountains. However, characteristics of the system are such that there is a finite statistical probability that under some condition, even with the most skillful receiver design, the airborne unit can select and track the wrong cycle. This could cause misleading steering information in the absence of a flag. The product liability implications of LORAN-C equipment certified for approach over land in the vicinity of obstructions are of major concern to many manufacturers. The system provides excellent and smooth RNAV capability in enroute, terminal and coastal airspace.

VLF-OMEGA does provide worldwide enroute RNAV capability with reasonable accuracy. Although some new designs offer lower cost, it remains quite expensive. The combination of OMEGA and VLF is needed for good worldwide operation. VLF-OMEGA has lots of nuances. Since the signals are in the high audio range and very noisy under good conditions, it is quite susceptible to radio frequency interference from other equipment, atmospherics, conductivity variances, polarcap absorption, and multipath/diurnal effects. VLF

enhancement of the OMEGA System provides one example in which an interprising company (Global) saw an opportunity to use existing signals in space in a unique way, developed products, gained domestic and international recognition of the system and satisfied a major market need. Of course, the Navy reminds us occasionally that we can't count on VLF and sometimes surprises people by reformatting the signals.

NAVSTAR is a bit of an enigma. It is a military system. NAVSTAR/GPS specifically was designed for high anti-jam (AJ) capability and for limited access and selective denial. It was not designed for cost-sensitive commercial users. With P code, it appears that the system can provide accuracy sufficient to drop 5 out of 5 bombs down the same hole. (Now there is serious concern that the undegraded C/A signals might be sufficiently precise to permit an enemy to drop 5 out of 5 bombs down a little larger hole.) Furthermore, the later satellites are designed to provide nuclear monitoring capability. These powerful military capabilities would appear to make NAVSTAR satellites a prime target for an aggressor's "killer satellites" if we should become involved in major hostilities. Of course, if the satellites offered essential, worldwide civil navigation of great precision, then presumably they would be a less likely target.

In DOD's zeal to sell the system to an increasingly cost-conscious Congress, all potential users (military and civil) have been pyramided together to justify the costs of this primarily military system. Of course, if everyone is supposed to be able to use the system, then it should be optimized for every user's needs (civil and military) and then, every user should pay his fair share accordingly. Although the system is well into the full scale development phase, many technical, economic and political issues remain. These questions should be resolved before the fate of our existing systems can be properly determined. Will foreign users who will have access to the system pay part of the cost? Who controls the "on-off" switch? Can we obtain international acceptance of a system controlled by the U.S. military? What do we do for backup if satellites are blasted from space or disabled by high intensity laser beams? When will NAVSTAR really be available? What C/A signal accuracy will really be available? Does accuracy degradation obviate use of the signals by geophysical survey and land based "position/location" users? If differential NAVSTAR is employed to re-establish accuracy of the signals in the vicinity of airports, major cities, etc., what has been gained by the original smearing of the C/A signals? If the technology is reasonable and well within the state-of-the-art, why has it been necessary to fund several companies to develop pre-production user equipment at an aggregate level of roughly $200 million?

The Aerospace Daily of February 21, 1980, indicated that NAVSTAR will cost $5.3 billion more than the system it replaces through the year 2000 and that the turnoff savings are trivial by comparisons. Remaining expenditures for essential satellites and spares is estimated at $1.3 to $1.6 billion, depending on whether purchasing is a block buy or piecemeal. Given basic financial resource limitations, with $100 billion annual federal deficits forecast, it remains questionable to me whether Congress will continue to authorize full funding for NAVSTAR.

Before summarizing some recommendations, it seems appropriate to briefly digress. More than 20 years ago, after a protracted debate on navigation systems for the future, it was determined that civil aviation would use VOR/DME and military aviation would use TACAN. As a consequence, in the early 60's, the then Director of the FAA R&D told us at a planning conference like this one, that no more NDB's (non-directional beacon stations) would be commissioned in the future and that others would be phased out in a relatively short time, our best sources indicate that in 1962, 461 NDB's were in place. By 1972, the population had more than doubled up to 1,069. By June 30, 1982, the total had almost doubled again and grown to 1,819. Today, the best, and often the only option, for establishing an instrument approach at a small domestic airport is to install NDB equipment and certify an ADF approach. In many parts of the world, aircraft are equipped with two ADF receivers and at most, one VOR/ILS receiver. RTCA's special committee #SC 146 just completed document DO-179, entitled "Minimum Operational Performance Standards for Automatic Directional Finding (ADF) Equipment," dated May 1982. The purpose was to update previous guidelines, more effectively use the allocated spectrum and provide the basis for a new TSO specification. King Radio has shipped more than 80,000 ADF's since NDB navigation was forecast to die. Although the low frequency non-directional beacon system was pronounced dead 20 years ago, it remains robust today. Existing simple systems never die--they don't even fade away.

What is the point of this long story and where do we go from here?

I suggest that we reconvene and talk about the shutoff of existing systems <u>after</u> the technical, political and economic issues of NAVSTAR are resolved, the system is fully deployed and cost/benefit is really demonstrated. Make NAVSTAR win on its own merits. Let the marketplace decide. Don't attempt to edict or legislate a victory: What we have is pretty good and it can be made better. Let us continue the installation of the more reliable solid-state VORTAC stations. LORAN-C can be vastly more useful at relatively low cost by installation of additional stations and nets in the U.S. West Mountain Region. Although the "TRIAD" system previously mentioned seems unrealistically utopian and perhaps divisive, we should not dismiss satellite systems optimized for civil users without further scrutiny.

The FAA should not plan on the basis that RNAV equipment is a minimum requirement nor should it invest significantly in improving VOR/DME accuracy or low altitude coverage.

It is prudent to plan a transition in the 1990's that includes satellite systems as a part of the system mix. But let's not plan to shut down existing systems until SATNAV becomes a clear winner.

Finally, I hope that my comments won't be interpreted as anti-GPS or anti-anything. I personally have high expectations for the benefits to be derived from future satellite navigation.

If/when the military GPS system becomes fully operational, and readily available to civil users for a modest access cost, we will make every effort to design, manufacture and market NAVSTAR user equipment that offers minimum cost of ownership and maximum user benefits.

JOHN W. KLOTZ
AVIATION CONSULTANT

In keeping with the pattern of the panel members preceeding me, I want to make the following introductions. After twenty-seven years of service in the Office of the Secretary of Defense, and having retired just seven years ago, I have no fear of reassignments to the Pentagon, no hope of political appointment in the Pentagon, and no personal desire to return to the Pentagon. Perhaps my remarks will insure my future in this regard.

By reason of my recent activities, and hopefully without exceeding my limited qualifications in the area of navigation, I offer a few observations on two programs that are featured in the "Proposed Systems" section of the Federal Radionavigation Plan:

- the military portion of the Microwave Landing System (MLS) which is known as the Joint Tactical Microwave Landing System (JTMLS)
- the Global Positioning System/NAVSTAR of the Department of Defense.

The MLS program is one which the DOT/FAA was assigned the administrative and budgetary initiative in 1970, while GPS has been under the auspices and initiative of the DOD and the military services, having been initiated in 1965.

Now for the few facts with respect to JTMLS, I note that on page 24 of Volume IV of the Federal Radionavigation Plan that:

> "RDTE (Army) funding in FY-1982 for the highly mobile tactical variant was zeroed out by Congress without prejudice. The USAF is now planning to initiate a 15-year program in FY-1983 for MLS to replace ILS."

The Army program, which was called out in the DOT, DOD, NASA MLS Plan of 1971, was initiated by a transfer of funds from the FAA in 1977 or 1978. Due to recent cost over-runs, the program has been on "hold" for about a year. My sources of information indicate that Army will cancel the program in the near future.

Using JTMLS as an example, one might conclude that it is going to take about 25 years to implement the military application of an "agreed upon" program between civil and military users. I don't know whether that is too long or not - it appears now that any extensive civil implementation may take as long.

My second observation is in the form of a question — "Has the 11-year interval of Army preoccupation with the JTMLS compromised Army operational readiness?" Afterall, the operational readiness and effectivity should be the ultimate criteria by which we judge the military departments use of the taxpayer's revenues. My answer to the question is: Evidently, up to this point, the Army believes that combat readiness in this area is adequate using the existing GCA units, although these units are costly in manpower and are becoming difficult to maintain. Moreover, the Army has rejected ordering into production the A-Scan Microwave Landing System which was fully developed and field-tested by the Army by 1974, and could have been put into production in 15 months. The A-Scan system was authorized for development in 1968 on the basis that Army operational readiness should be protected in case the MLS was delayed.

My third observation is with respect to the USAF proposed effort. I believe the USAF is moving on a schedule that is more consistent with worldwide civil implementation of MLS. After all, for reasons that are obvious, USAF transition to MLS will have to await fairly extensive worldwide civil implementation.

Now for a few observations on GPS. The defense budget, just passed by Congress, is the largest budget in the history of our country. I believe that it is the first time in the last several years that the USAF has supported GPS without intervention and direction from the Secretary of Defense.

The *cost comparisons* of a mix of navigation systems that were presented by the speakers earlier in the conference tend to obscure the fact that acquisition of GPS will cost between $6-8 billions. Is that a lot of money? I guess the ease in which one answers that question betrays his age, the date of the last course in economics, as well as political persuasion. The cost of GPS is only 0.5% of our national debt of $1144 billion! To carry that debt every year, the taxpayer must contribute $115 billion. And that $115 billion is more than half of what is appropriated for national defense! Viewed in other terms however, the GPS will cost between 1/4 - 1/3 of the 100 aircraft in the B-1 bomber program!

Another observation: While GPS is beginning to be called out as the prime system of navigation for military weapon systems, this does not mean that self-contained systems currently in use or projected for use will be phased out. It means that ultimately DOD will decide which is prime and back-up based upon experience with the GPS in terms of its vulnerability in a real threat environment. I think we all understand that while DOD is justifying $6 billion to Congress, it's a prime navigation system. Some of my other observations about the DOD rationale for GPS will be used in other forums.

Let me turn now to Administrator Helms' invitation to comment on his opening remarks. Your attention is called to one of the assumptions which he used in his list of five questions.

> "Assuming that the military's needs will require the U.S. deployment of GPS, and that only a small share of the cost of GPS operations, for the life of the GPS, would be allocated to civil users..."

I don't know the source of Mr. Helms' speech material, but according to documentation generally available in Washington, there is no basis to now use, or to continue to use the assumption stated by Mr. Helms.

The document I refer to in this connection was issued by the Department of Defense on March 1, 1982, and is entitled, "NAVSTAR Global Positioning System - USER CHARGES". In reading the report I note that it is a preliminary report to the Senate and House Committees on Armed Services. Also, the Department of Transportation was asked to join the Working Group on User Charges in November 1981. Finally, the report states that DOD will work with DOT and other cognizant federal agencies to fully explore the aviation issues discussed in the report.

But with all of these qualifications and stated reservations, the report goes on to develop a "tentative, order of magnitude charge estimate" indicating that the GPS Standard Positioning Service (SPS) users will be assessed about 57% of the costs of maintaining GPS over a 30-year life span. The SPS is the service offered to non-military users, and the estimated user charge is $370 per year for each subscriber. From this first draft of the user charge plan, it is apparent that the DOD intends to assess the civil users with the major share of the costs. In my opinion, DOT should get to the Congress promptly before this preliminary USER CHARGE report becomes final, and before the next edition of the FRP with a comprehensive statement of views of the civil aviation community.

Just briefly, with respect to Mr. Helms' question #5 on another navigation satellite study, I would strongly support such an effort provided it is international in sponsorship, and directed at civil navigation requirements. I have read a April 14, 1982, report of the European Space Agency, Aeronautical Satellite Program Board entitled, "Prospects for a Future Civil Worldwide Navigation Satellite System" which indicates a civil NAVSAT can be deployed for $1.2 billion in capital costs, giving access to accuracy performance which is available only to military users of the U.S. GPS.

Thank you.

HARRY SONNEMANN
DEPUTY CHIEF ENGINEER FOR
SYSTEMS ENGINEERING AND TECHNOLOGY
NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

Several of the panel members that spoke noted that new uses are frequently found for existing systems which can significantly extend their utility. It may be of interest in this connection that I have just received a preliminary report on the use of TACAN range data for Shuttle Orbital navigation. Measurements were made on STS-1, 2, and 3, and the data analyzed to derive performance parameters. This performance analysis was then used to predict STS-3 performance, and STS-3 data was subsequently processed in a manner which was functionally similar to the proposed on-board software as a check on the predictions. The predicted performance for a 150 NM orbit for a 1 sigma end-of-track position error was 1000-2000 feet. Performance using the STS-3 TACAN data yielded a position error at the end-of-track of 1000-2000 feet. Using the TACAN data from STS-3 the position error propagated one revolution was 8500 feet, well within the predicted error range. These excellent results will provide a viable backup navigation capability to the Shuttle and add another new use to an existing system.

Let me now launch into responding to Mr. Helms' 5 questions. Before I do, let me note that I continue to be troubled by the attempts over the years to look at the optimum future navigation system or system mix as that mix which has the lowest per unit life-cycle cost based almost solely on the ability of this new system or system mix to satisfy the user requirements, without serious consideration being given to the remaining life of the equipment in service. It has been my position that when considering the merit of replacement systems one must examine the marginal utility of the new system, i.e., the question whether the improvements to be derived from the new system are sufficiently attractive to merit early replacement of the equipment in service, or replacement by the upgraded system at the end of service life. If the additional capabilities of the new system or system mix is not required to meet the needs of the user, the user's choice is most likely to be the system configuration that meets his requirements at minimum cost. Unless the new system or system mix can be competitively priced, the economics of scale hoped for in the price structure of the new capability will not be realized. I have not seen any proposals which suggest that the government would consider underwriting the cost of making the changeover to the new capability sufficiently attractive to the user to be able to realize the economies of scale. The studies have, for the most part, ignored the marginal utility issue which drives the investment decisions of the user community.

Now to the five questions:

1. Do I see a need for a change in the navigation systems mix? Not in the foreseeable future.

2. I believe that we need to retain RHO/THETA VOR/DME in the system at least until the turn-of-the-centruy, to insure the availability of short-range capability if the area systems are deliberately disabled or denied to us.

3. There is no clear benefit to transitioning from the present mix to a single universal navigation system such as GPS, or a combination such as GPS and VOR/DME.

Studies have not borne out the contention that this would be cost-effective, when phase-over from current systems is tied to private sector investment decisions. Even if one were to start with a clean slate, it is unlikely that one would depend on a single system. At a minimum one would expect to have a backup system with a different failure mode in place to provide global, regional and local coverage in a degraded mode. This suggests that Omega, Loran-C and VOR/DME might be a reasonable core system as a complement to GPS. With the precision mode denied to the civil user, the marginal utility of GPS becomes extremely low for civil applications, making a voluntary phaseover by a significant fraction of the user population before the year 2000 very unlikely.

4. It has been my observation on numerous occasions in the past that it must be the precision military navigation requirements that justify the U.S. deployment of GPS and that this requirement must be sufficiently critical to the military to be willing to shoulder the cost of deploying and maintaining the system. Use of the system by the civil sector should be viewed as an "added benefit" which ultimately may reduce the overall cost of maintaining the navigation system mix to the government, but is unlikely to have any early monetary offset flowing from contributions by the civil sector. It is prudent to point out in connection with satellite navigation systems, such as GPS, requiring simultaneous acquisition of a number of signals to achieve the system accuracy, that is necessary to have an operational configuration in place with the intrinsic advertised capability (i.e., the entire constellation) to make it possible for the potential civil users who must make investment decisions to determine whether the system achieves the claimed accuracy. Even more important is for them to determine the extent to which the Geometric Dilution of Precision (GDOP) affects the operational utility of the system. Since in the GPS system the GDOP is dependent on both the number of satellites and their spatial configuration at any given time, a thorough evaluation of the dynamic characteristics of the total system is essential before comitments by the civil user community are likely to be made. I would, therefore, suggest that no significant move in the direction of GPS acceptance should be anticipated until the operational capability of the system has been fully demonstrated through two complete seasonal cycles. Since some civil user receiver equipment base will be required to reach a concensus within the civil community, I would expect that 3-5 years will elapse after the full implementation of the system before sufficient financial commitment. With a 10-year phaseover period to amortize existing equipment life, I would expect that, even with no required contribution to the operation of the system by the civil sector, GPS will not constitute a major fraction of the navigation mix capability before the year 2000.

5. As indicated under the fourth question response, I do not feel that it is prudent to plan a transition in the 1990's from the present systems mix to a satellite based navigation system. Even in the year 2000 I do not see a total dependence on a single system for essential navigation requirements. As noted earlier, graceful degradation must be provided with systems that do not have the same failure modes. I do not think that another study to determine the practicality and cost-effectiveness of a satellite-based system is warranged. The demonstrated effectiveness of GPS, once it becomes operational, and the user acceptance should be the vehicle for assessing the ultimate utility of high precision, real-time navigation capability. We already know that if intermittent

use is acceptable, the TRANSIT system is a highly effective and reliable capability, which meets many high precision requirements in stationary applications. Coupled with OMEGA, it also provides a useful means of containing the growth of position errors, and in conjunction with inertial platforms provides a means to contain the drift of these systems. It is my view that the capability of a satellite-based navigation system has been amply demonstrated. The degree of precision for a system requiring simultaneous acquisition and processing of data from satellites in varying orbital positions has yet to be demonstrated. A similar system for the civil community, whether U.S. or international, operating in parallel with GPS does not seem to me to be economically realistic. I do feel that transmitting the GPS information from the host platform via a satellite link to selected ground stations may be a viable means of achieving better Air Traffic Control. Using an additional GPS transmitter at the end of airport runways may also provide a precision landing capability permitting operation in poorer weather conditions. Tests should be planned to evaluate this capability.

Finally, let me summarize my major point with regard to future navigation systems planning.

1. We must recognize that the user investment which exists must be taken into consideration in phasing decisions for new systems.

2. GPS capability for the civil user must be demostrated with the full on-orbit system before any significant user commitments can be expected.

3. GPS coupled with end-of-runway transmitters may provide precision landing capability.

4. Transponding GPS data from the platform to selected ground stations could significantly increase air traffic control capability even with the clear signal mode only.

5. A parallel civilian GPS system is not in the cards. It is not affordable even if we propose to scramble the signal and mandate user fees to gain access. Modifying the GPS system follow-on satellites to optimize civil user capability, including possibly scrambling the signal to recover some of the operating costs as user fees is worth considering, but not until the civil user community has reached a concensus that the GPS system is indeed the preferred navigation system.

6. Back-up systems with different failure modes for all services must be maintained.

ALEXANDER B. WINICK
AVIATION CONSULTANT

Rather than attempt to answer specific questions arising from the Administrator's opening remarks, I would like to make two general observations. They are related to the entire process of navigation system evaluation which has been going on over the past two years, and are not intended to make a judgment as to which of the candidate navigation systems is most suitable.

I believe that the entire issue of duplication of navigation services has been grossly exaggerated. One can suspect that this was done to serve a particular partisan purpose, but in any case, it hardly represents a true assessment of the current operational environment. There are a number of different systems in use, but not nearly the horror list published in the GAO reports, which included navigation systems which barely saw the light of day; which were very much special purpose systems used only by a few; and in some cases, were not at all relevant. The systems now in use reflect the diverse need of aviation, the needed redundancy for safety and, in some instances, systems being used during a transition period from one to a new and improved replacement. The degree of unnecessary duplication in civil navigation systems is small, and should not be the major rationale for introducing a new one, GPS or otherwise. In my view, exaggeration of the duplication issue gives the impression of being a political objective and has done a disservice to the honest merits of the new satellite technology. It will be difficult for GPS to overcome all of the claims and half-truths offered in its behalf.

A more important question deals with the entire process of planning for a system change. Is it really possible to select a new and untried system at one point in time (1983), and know with full assurance that the system will be a suitable replacement 10 years hence? Where is the body of knowledge that makes such assurance possible? I believe that the basic premise of the FRP is faulty and that this kind of a decision making simply cannot take place. I suggest that a more sensible procedure and one that has worked in the past is to first permit the use of a new system as a supplement to what now exists to fulfill requirements which are currently unfulfilled. If it does that job, it will win adherents and gain user confidence. And when it does, it can then go about demonstrating that it does other things better than the current standard and is worthy of being considered a replacement. The process is simple and logical, and it need not disturb the conservative user, who may be happy with what he now has.

For Loran-C and Omega, this process is underway. Due to technological limitations, neither of these systems may go any further than being a supplement to VOR/DME. With respect to GPS as it now exists, let it demonstrate its capabilities as a supplement, particularly for oceanic use. Then we can really learn something about its operational suitability and begin to think about the future (assuming, of course, that all the firghtening institutional issues have been resolved).

What I have described is not the dramatic way (no command decisions), but it just may be the way that system changes are actually made.

SUMMARIES OF STATEMENTS
BY ORGANIZATIONS REPRESENTING THE
USERS OF THE FUTURE NAVIGATION SYSTEMS

Following the formal presentations, an opportunity was provided for the organizations representing the various users of navigation systems to present statements of their views and concerns relating to the future navigation system and the activities leading to the selection of a national navigation system. In most cases the remarks were impromptu and required that the summaries be prepared from audio tapes recorded during the conference. These summaries are presented in the following pages with the numbered items responding to the Administrator's five questions.

REMARKS SUMMARY FOR MR. MICHAEL BAIADA,
RANSOME AIRLINES, REPRESENTING THE
REGIONAL AIRLINE ASSOCIATION

Mr. Baiada stated that he was happy to see that area navigation is finally coming into its own. The new, advanced avionic systems, including EFIS and area navigation, will of necessity change the pilot from a seat-of-the-pants flyer into a system manager. Ransome Airlines, in conjunction with the FAA, has been collecting MLS operational data on passenger flights since March 1982. Ransome finds that MLS has numerous advantages over ILS and will be an integral part of the future navigation system.

The system of the future should be able to use different sources of navigation, i.e., VORTAC, LORAN-C, Navstar GPS, and Omega/VLF as RNAV systems with MLS or ILS for landing, with the choice based on the market place. The 3D RNAV computer should have route and fix information storage for the area of interest and the equipment should be able to choose the most precise navigation aid available during a particular mode of flight. The computer must be flexible so the pilot can make changes in flight but it should also protect the aircraft and the system against blunders.

REMARKS SUMMARY FOR MR. WILLIAM T. HARDAKER, AIR TRANSPORT ASSOCIATION (ATA) OF AMERICA

Mr. Hardaker stated that he believed the background and detail provided by the excellent technical panel presentations of the first day support where the system is headed. He stressed that all decisions on future navigation systems must carefully consider cost benefit and that selections must be based on requirements. On the Administrator's questions, he provided the following responses with the caveat that they had not been coordinated with the airlines but represented a consensus to the best of his knowledge:

1. ATA sees VOR/DME as a primary navigation service in the domestic area for at least the next 15-20 years. Omega will be used in an increasing degree as a supplement for en route navigation. For over-ocean service, Omega, either alone or in combination with inertial, will increase in use as will the newer, more cost effective inertial systems. For precision approach, ILS will continue to be essential for a number of years to come. MLS usage will depend to a large degree upon continuing demonstration of potential benefits.

2. Mr. Hardaker stated that the airlines have long believed that RNAV should be at the user's option. Further they feel it should not be a disbenefit to those who do not install it. He indicated that radial navigation should be retained through at least the year 2000, and that VOR/DME accuracy should be improved for selected facilities but today's signal format should be retained so that it doesn't require replacement of the airborne equipment.

3. ATA sees no clear benefit at this time in a transition to GPS or to a mix of GPS and VOR/DME.

4. Mr. Hardaker stated that with the precision signal of the GPS not available to the civil community and the vulnerability of the system to significant degradation or loss of service, the GPS does not seem attractive to the ATA. He stated that he felt the airlines have kept an open mind on satellites as a possible system in the future, but that we have not as yet come to that point. One needs to also consider the user cost of retrofit and maintenance costs.

5. The ATA cannot see a need to transition to a new navigation system in the 1990's, until a need is manifested for increased capacity, safety, surveillance, and/or communications. It is felt that satellites certainly will be a candidate system. Mr. Hardaker stated that the ATA has concluded that sometime in the distant future satellites may be the answer, but he did not recommend another study at this time.

REMARKS SUMMARY FOR MR. VICTOR J. KAYNE, SENIOR VICE PRESIDENT, TECHNICAL POLICY AND PLANS, AIRCRAFT OWNERS AND PILOTS ASSOCIATION (AOPA)

1. Mr. Kayne stated that there is no urgent need for a change in the navigation system mix, provided that the present system facilities are not reduced. Better coverage below present line-of-sight would be welcome, however, the average general aviation owner will be satisfied with adequate VOR coverage, supplemented by DME's and NDB's at strategic locations.

2. AOPA does not support the idea that area navigation capability should be a minimum requirement for all who wish to use the National Airspace System.

3. Mr. Kayne indicated that the present postulation of the GPS has too many disadvantages for civilian acceptance. Whether another satellite system would provide advantages remains to be determined.

4. AOPA does not consider the proposed GPS user charges to be reasonable and feels that this alone would cause rejection of GPS as the single future system. Also, the civil (SPS) accuracy of GPS is insufficient to support its use as the sole future radionavigation system.

5. AOPA believes that the FAA should continue investigation of a satelite-based navigation system for possible use in the future, either alone or in combination with VOR/DME. A system that can provide multifunctions including surveillance and communications would be an added attraction. Other functions to be considered are search and rescue and collision avoidance.

Mr. Kayne concluded his remarks stating that more information and better answers are needed before any substantive changes are "set in concrete," especially changes which may freeze the system for the next twenty years.

REMARKS SUMMARY FOR MR. EDWARD KRUPINSKI, AIR LINE PILOTS ASSOCIATION (ALPA)

Mr. Krupinski stated that he could not express an ALPA position on any of Mr. Helm's questions but that he could give his views which he believed generally reflect those of the Air Line Pilots Association.

1. In view of the fact that the FAA has recently contracted for the replacement of about 900 VORs, nearly a total replacement of this system, Mr. Krupinski stated that he believed it unthinkable to consider scrapping the VOR system in the next 15-20 years. Further, he stated that replacement won't occur until a much better system is brought about by technology, which has not happened yet. In his view, we are definitely faced with a mix of navigation capabilities for some time.

2. Mr. Krupinski stated his total agreement with Mr. McIntosh of NBAA that there should not be a specific requirement for the pilot to carry RNAV equipment. This should remain the pilot's prerogative. Mr. Krupinski expressed concern relating to the ability of the ATC controllers to accommodate the various capabilities, such as RNAV, pressed upon them. He further stated that, in his view, VOR/DME accuracy and low altitude coverage were not as good as they should be and if they can be improved, this should be pursued.

3. Concerning the evolution to a single universal system, such as GPS, Mr. Krupinski stated that he felt very uncomfortable about NAVSTAR GPS. There appear to be many unanswered questions in terms of the civil use of GPS. However, he stated that he is not as concerned as some about the denial of accuracy or denial of system use in case of emergency. He believes that we all will be faced with not having navigation capabilities in case of real emergency, and referred to the SCATNA plan (Security Control of Air Traffic and Navigational Aids) in which this is clearly indicated.

4. Mr. Krupinski stated that in his view, NAVSTAR GPS should be pursued some more and that better resolution of the open issues should be obtained. More coordination between the civil and military is necessary before the system can be developed and deployed to satisfy civil use. He indicated that GPS was one way but that there may be other ways to get better navigation coverage, especially through the use of satellites.

5. Mr. Krupinski stated that he believed that the door should be left open for considering the use of satellites for various purposes. He expressed his view that the only thing we see in the way of technology down the line for navigation and other improvements in the use of satellites. He believed that there is general agreement on that. Mr. Krupinski stated that we also need to be thinking about how we're going to improve the surveillance capability for the controller. This is possible through the use of satellites, and even though their cost at this time is a concern, satellites are what we're going to have to look for in the 21st century unless someone comes up with something better. He stated that if we are going to spend up to 10 billion dollars for a new ATC computer system, this might be the time for us to be thinking of satellite systems for improved surveillance and other ATC functions.

REMARKS SUMMARY FOR MR. FREDERICK B. MCINTOSH, NATIONAL BUSINESS AIRCRAFT ASSOCIATION (NBAA)

Mr. McIntosh stated that the domestic aviation navigation system must be a common system useable by the greatest number of aircraft and compatible with the air traffic control system. This common system must be capable of utilizing area navigation technology and be suitable for non-precision approaches. Until there is a proven better alternative, VORTAC should be retained as the common navigation system for U.S. aviation. The VORTAC system should be modernized and facility locations reviewed for maximum effectiveness. Other systems should be authorized where applicable and compatible with the ATC system. The ATC system must encourage the increased use of area navigation technology to provide more efficient use of the nation's airspace.

The MLS installation priorities should be for airports tha do not have or cannot qualify for ILS. The replacement of existing VHF ILS was the last priority for MLS development. The FAA must remember this when planning MLS installations.

Helicopters are also part of the business fleet and helicopters need suitable navigation signal coverage in the areas where they fly.

Minimum Equipment Lists (MEL) should be standard for all aircraft, not just air carriers and aircraft should only carry the navigation equipment necessary for the conduct of the flight. Everyone should remember that where safety is not involved, the system should be designed for the convenience and economies of the aircraft and its operator and not for the control function.

RNAV should be designated as the primary navigation method above a certain altitude, hopefully FL-180 but at least FL-240 and above. Thought should be given to requiring RNAV for certain operations.

REMARKS SUMMARY FOR DR. DONALD W. RICHARDSON,
REPRESENTING THE HELICOPTER ASSOCIATION INTERNATIONAL (HAI)

Dr. Richardson stated that the helicopter fleet is just a little over 9,000 operating vehicles. One of the things the helicopter community needs is all area coverage, including low altitude with approach capability. They need the requirements of the Federal Radionavigation Plan today, i.e., plus or minus 2 nm route widths with a minimum en route altitude of 1200 feet. Also needed is a navigation signal to support approach procedures to an MDA of 250 feet. In the future, NAVSTAR GPS might be able to provide this service, but the service needed today. LORAN-C appears to be the only answer within the next decade. Dr. Richardson recommended that we certify LORAN-C within the bounds of safety and allow its use as an RNAV system where possible.

Concerning Mr. Helms questions, Dr. Richardson made the following comments:

1. There is absolute support for the continuation of the current mix of systems. The use of RNAV and LORAN-C should be promoted, particularly where there is no VORTAC coverage.

2. RNAV equipage should not be required, but should be an option to the user.

3. Conversion to a single system should occur only if it will safely answer all needs. A single system may not be practical.

4. No comment.

5. There is no reason not to continue the exploration of the capabilities of satellite systems in the future for helicopters. However, the need is now and activities to meet the immediate helicopter community requirements should not be delayed.

SECTION 8
CONFERENCE SUMMARY CONSENSUS

At the end of the conference, Mr. Poritzky presented the following remarks as a summary of the views expressed during the conference by the speakers and attendees. The group appeared to agree that this summary represented a fair assessment of the situation at that time. These comments were preliminary in that they summarize the sense of the conference at its conclusion. The attendees were asked to respond more formally within sixty days (by October 4, 1982). These more formal responses will be considered in determining the FAA's preliminary recommendations to the Secretary of Transportation for the future radionavigation system mix.

Mr. Poritzky stated that the views are as follows:

o Recognizing that the aviation user community will pay a fair share for the services it uses, there is broad agreement that the present navigation system mix is satisfactory, with each element having an important role--VOR/DME for the domestic short-range system, OMEGA for over-ocean and long-haul primary or updating service, LORAN-C where available to service helicopters and other special uses, NDB where needed, and increasing use of inertial reference systems in larger aircraft for both domestic and over-ocean operations.

o There is no perceived need to change VOR/DME other than to improve the low-altitude coverage. The community believes that where increased accuracy is needed, it should be achieved by modifications of the ground system rather than by dramatic changes in airborne system hardware (although it is recognized that digital avionics are gradually providing increased accuracy). OMEGA and LORAN-C should continue to be available for use, and LORAN-C should be exploited and extended if necessary to serve the special needs of helicopter operators.

o The community believes that area navigation should not be a basic requirement to enter the system and should therefore not be a prerequisite in the use or deployment of VOR/DME, although there is broad recognition that area navigation equipment will grow into ever wider use. Nevertheless, basic VOR/DME should remain available and conveniently sited for those who wish to use it directly, with continued use of VOR-only to be expected, with area navigation as an option. It is anticipated that multiple DME usage will grow, in part to update inertial navigation systems.

o With respect to NAVSTAR GPS, there is an almost universal view in the civil user community that until the full system has been implemented and operational for several years, no determination of performance is feasible and, therefore, no implementation decision should be made now. If GPS is implemented by DOD and made available for use, the marketplace should determine its utility and desirability, but only after extensive experience.

- There is a unanimous view in the community that the aviation system should never be put into a position where it must rely on any single system.

- The user community appears unanimous that civil aviation should not become a partner in NAVSTAR GPS in any financial sense before all its capabilities are known and demonstrated. This view is held even under the assumption that only a relatively small share of the cost of GPS operations for the life of GPS would be allocated to civil users. This view is held widely with respect to NAVSTAR GPS as a single universal system, and also for a NAVSTAR GPS-VOR/DME combination.

- The user community agreed on the importance of timely failure detection warning (at least as good as in current systems) in any system intended for civil use.

- With respect to planning for future applications of satellite services other than NAVSTAR GPS, the user community recognizes that satellite applications will find a place in the civil aviation system, perhaps first in cost-effective fixed-service satellite communications trunking; and possibly for over-ocean air-to-ground communications, perhaps using satellite services shared with the maritime service.

- There was fair agreement that it would be desirable to examine multi-function satellite possibilities, and full agreement that such multi-function systems would have to be considered in an international context.

SECTION 9

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